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DEVELOPMENTS ON HIGH TEMPERATURE FIBER OPTIC MICROPHONE

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SUMMARY

A fiber optic microphone, based on the principle of the fiber optic lever, features small size, extended bandwidth, and capability to operate at high temperatures. These are requirements for measurements in hypersonic flow. This paper describes the principles of operation of fiber optic sensors, a discussion of the design of a fiber optic microphone, the functional elements and packaging techniques of the optoelectronic circuitry, and the calibration techniques used in the development of the high temperature fiber optic microphone.

Principles of Operation

The fiber optic microphones that are initially being developed are intensity-modulated (fiber optic lever) microphones. The fiber optic lever responds to changes in light reflected from a vibrating surface. Light from a light-emitting diode is directed through a transmitting fiber, reflected from a mirror on the bottom side of a stretched membrane, collected by a bundle of receiving fibers, and detected by a photodiode. When the membrane vibrates, it modulates the intensity of the received light [1]. The fiber optic lever microphone has three primary advantages over the condenser microphone. First, because acoustical signals are transmitted optically rather than electrically, there is no loading by cable capacitance or 60 Hz noise due to capacitive pickup. The usual practice of locating the condenser microphone preamplifier as closely as possible to the microphone cartridge is not viable at high temperatures. Secondly, the same loading effect limits the minimum practical size of a condenser microphone to about 1/8"; but the minimum size of a fiber optic microphone is limited by the size of the optical fibers. These fibers are currently available in diameters as small as 0.0039". Finally, the fiber optic microphone has an inherent advantage in bandwidth. The reason for this stems from the fact that the condenser microphone responds to the mean displacement of the membrane, while the fiber optic microphone responds to the displacement at the center.

Microphone Design

A bundle of optical fibers, containing a central transmitting fiber and several peripheral receiving fibers, are pressed into a hypodermic needle. After the latter is inserted into the microphone body, the assembled cartridge is placed into a fixture, where the membrane is excited acoustically. The hypodermic needle is positioned until the microphone output is maximum, then locked in place by means of a pen vise at the bottom end of the cartridge.

The active diameter of the membrane is not the outside diameter of the cartridge, rather the diameter of the inside hole in the tension ring. In this manner microphones of very small active diameter can be constructed.

Microphone Calibration

Most conventional methods of microphone calibration are not capable of being used in high temperature environments. The electrostatic actuator method was used because of its ability to withstand high temperatures. Figure 1 shows the electrostatic actuator setup. Three quartz pins are used to support the actuator electrode directly above the microphone. The quartz pins maintain a constant distance between the microphone and the actuator as temperature increases. This is an important property to preserve the integrity of the calibration at high temperature. The primary disadvantage of this method of calibration is that the sound pressure levels generated by the electrostatic actuator are low. As a result of this fact, the noise level of the system has to be minimized to allow for the calibration signal to be distinguished from the system noise.

Optoelectronics

The optoelectronics primarily consists of the light-emitting diode (LED) which outputs light to a single transmitting fiber, and the photo detector-amplifier which amplifies the modulated light gathered from an array of six receiving fibers. Figure 2 is a block diagram of the optoelectronics. Several techniques are used to achieve the lowest system noise level possible. First, the power supply is wrapped in a shield to reduce the effects of electromagnetic interference. In addition, regulators are used to supply power to optoelectronic components because of their excellent noise suppression characteristics. Other noise reduction techniques such as braiding all wires to switches and connectors provided additional noise immunity. The result of these noise reduction techniques was a system noise level at the photodetector input of less than 10 nV. This level is 10 dB below the initial version of the optoelectronics that did not stress noise reduction. Another design goal for the optoelectronics is to get maximum power into the receiving fibers and to the photodetector because the signal-to-noise ratio increases in proportion to the square root of the power. To achieve this goal, great care is taken to assure that the photo diode and the photodetector are properly aligned with the fiber optic cable through the use of SMA connectors. Also incorporated into the optoelectronic design is an automatic zeroing circuit to compensate for any DC drift due to temperature changes. The electronics are housed in a portable shielded instrumentation enclosure.

CONCLUSIONS

The fiber optic microphone was successfully tested in a laboratory setup. The microphone was operational at temperatures up to 1000 °F, it had a frequency response of 100 kHz, and dynamic range calculated to be 190 dB. Figure 3 shows the results obtained during a typical calibration. The successful implementation of the fiberoptic microphone is expected to lead to the development of a higher temperature microphone as materials are developed that can withstand the temperature goal of 2000 °F.

REFERENCES

[1] F.W. Cuomo "Pressure and Pressure Gradient Fiber-Optic Lever Hydrophones," J. Acoust. Soc. Am. 73, 1848–1857 (1983).

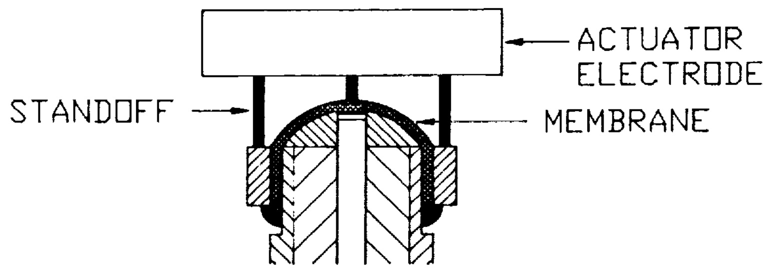

FIGURE 1. ELECTROSTATIC ACTUATOR FOR HIGH TEMPERATURE MICROPHONE CALIBRATION.

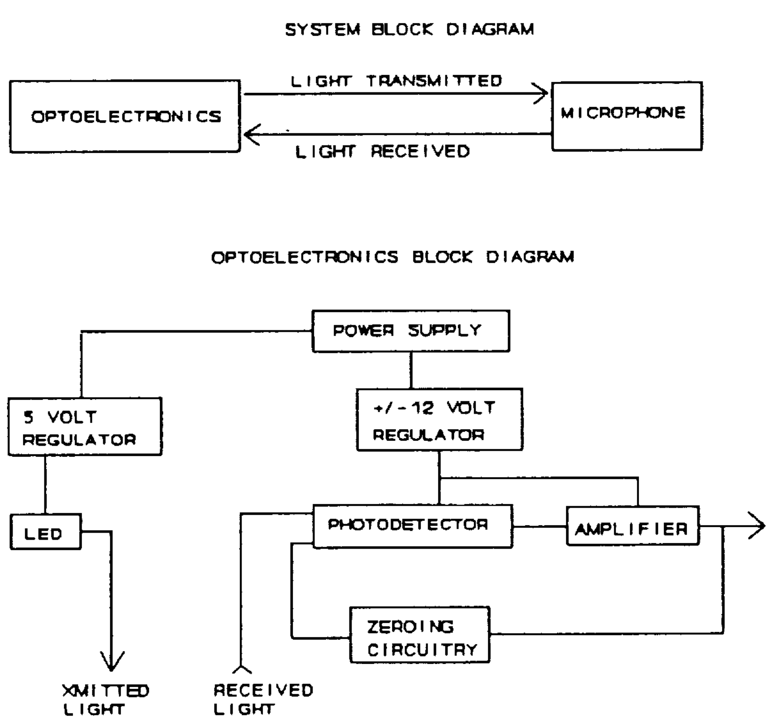

FIGURE 2

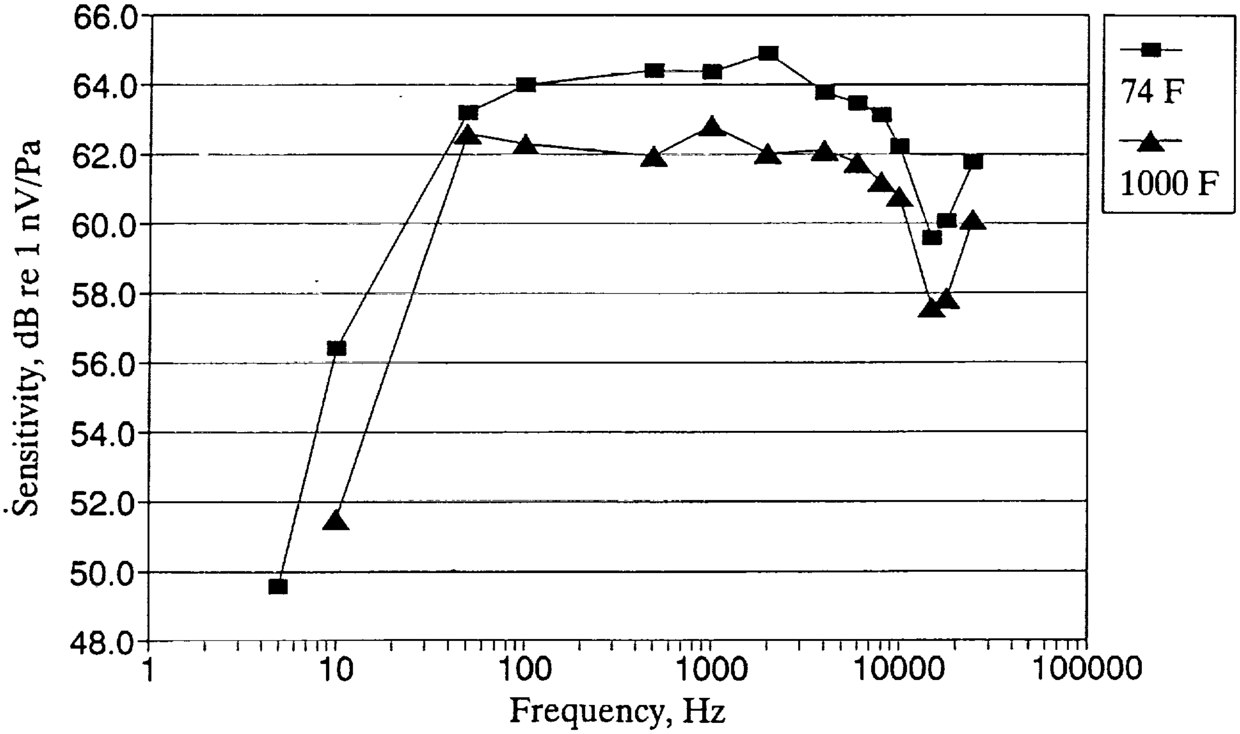

FIGURE 3:TYPICAL MICROPHONE CALIBRATION