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Figures 8 and 9 show the receiving sensitivities of small sized sensors. Figure 8 gives responses to μ30 and μ100. Both have the highest peak of about 10 dB in the 200-300 kHz range. While μ30 starts to have reduced response beyond 600 kHz, μ100 maintains good responses to 1300 kHz. PicoHF sensors on Fig. 9 have similar sizes like Pico sensor (response shown in Fig. 1b) and show the peak near 500 kHz, like Pico. The high frequency responses to 1.5 MHz are similar among the three, but HF versions keep responses to 2 MHz.

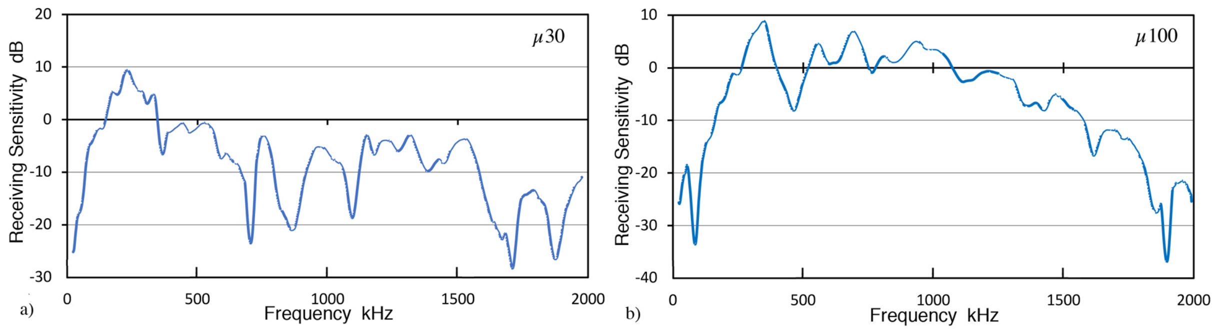

Fig. 8. Receiving displacement sensitivities in dB in reference to 0 dB at 1 V/nm against frequency in kHz. a) PAC μ30, b) μ100.

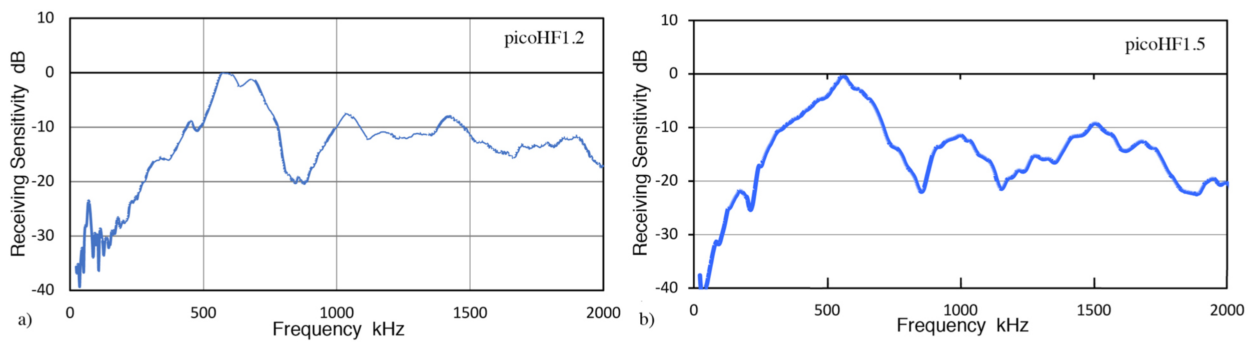

Fig. 9. Receiving displacement sensitivities in dB in reference to 0 dB at 1 V/nm against frequency in kHz. a) PicoHF1.2, b) PicoHF1.5.

Fig. 10. Receiving displacement sensitivities in dB in reference to 0 dB at 1 V/nm against frequency in kHz. SE1000E (red curve), AE900M (blue curve).

Figure 10 shows the receiving sensitivities of sensors designated as broadband. The response of Score Atlanta (formerly DECI) SE1000H is given in Fig. 10a). This was reported in [3]. SE1000H shows many peaks (of above –20 dB) from 10 kHz to 680 kHz. Figure 10b) is the response of NF AE900M and shows the mean value (±SD) of –15.6 ± 2.1 dB over 1 to 2 MHz.

Another broadband sensor is from Fuji Ceramics, REF-VL. It has a smooth spectrum, as shown in Fig. 11. The displacement response (blue curve) is similar to Olympus V101 (0.5 MHz transducer) [1], with a dip at 963 kHz. Here, both displacement (blue curve) and velocity (green curve) response spectra are shown so that the latter can be compared to factory calibration (red curve) only available in velocity response. The two velocity spectra matched well between 30 to 930 kHz. The average difference (±SD) was 3.21 ± 1.18 dB. Also plotted in Figure 11 is the velocity response of AE900M, converted from the displacement spectrum in Fig. 10 (purple curve). In the displacement to velocity conversion, the low frequency parts are raised so that the entire spectrum becomes flatter. In this case, the average became 24.33 ± 4.35 dB over 20 kHz to 2 MHz. This dB scale is in reference to 0 dB at 1 V/m/s. A calibration curve for AE900M sensor was recently reported [7] and matches to the present curve well in terms of the peak sensitivity and the amplitude range over 0 – 2 MHz. The sensors tested in this work were five to more than ten years old, but the sensitivities are comparable, respectively.

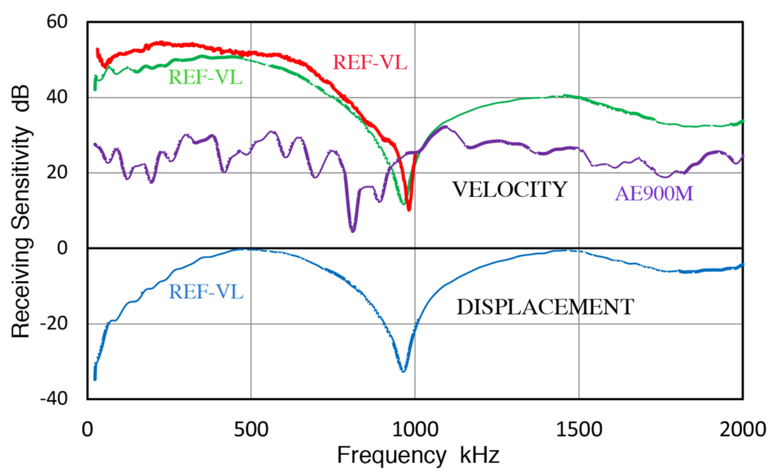

Fig. 11. Receiving displacement sensitivities in dB in reference to 0 dB at 1 V/nm against frequency in kHz for REF-VL (blue curve). Receiving velocity sensitivities in dB in reference to 0 dB at 1 V/m/s against frequency in kHz for AE900M (purple curve), REF-VL (green) and factory calibration for REF-VL (red).

Discussion

Displacement sensitivities (Rx) shown above can be converted to velocity sensitivities (Rv) or pressure sensitivities (Rp) by the following:

$$Rv = Rx - 20 \log (2\pi f) + 180$$

and

$$Rp = Rv - 143.3,$$

where f is in Hz, Rx, Rv and Rp are all in dB scale. Reference for Rv is at 0 dB for 1 V/m/s and for Rp at 0 dB for 1 V/μbar. At 20 kHz, 20 log (2πf) corresponds to 102.0 dB and Rv is 78 dB higher than Rx. At 2 MHz, the difference is reduced to 38.0 dB. These changes can be seen in Fig. 11 above between blue (Rx) and green (Rv) curves. The above conversion is shown as the last three columns in the sensor data file.

Appendix

An Excel file accompanies this technical note. The data of this file is to be used only for research purposes of non-commercial nature. (For other uses, contact the author at ono@ucla.edu.) Each column provides receiving displacement sensitivities in dB in reference to 0 dB at 1 V/nm. Some sensor names are only given in letter codes since no agreements with the manufacturers were formalized as to the publication of numerical data. A total of 41 spectra are given. Two of them are duplicates of the same type sensors (KRN and PAC R6α). The last three columns on both sheets provide examples of conversion to velocity or pressure sensitivities. The first column gives the values of $20 \cdot \log(2\pi f) - 180$ that corresponds to the frequency (in kHz) given in column A, the second the velocity sensitivities (Rv), and the third pressure sensitivities (Rp).

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