## 6.8 Piezo pickup vs. microphone

An acoustic guitar fitted with a piezo pickup offers two possibilities for recording: airborne sound via a microphone, and structure-borne sound via the piezo. Since the sound radiated by the guitar body is not particularly loud, a recoding microphone needs to be placed as close as possible to the guitar – which a) obliges the guitarist to maintain substantial "positional discipline", and b) generates the permanent fear that in a moment of negligence he/she might ram that one-of-a-kind pre-war Adirondack-fir-top into the mike. Indeed, these shortcomings led to the development of the piezo pickup in the first place: a pickup enabling the player of an acoustic to move around. It sounds differently, though. The preceding chapters have shown that the piezo pickup can deliver the full frequency range of the human hearing with good quality. Since non-linearities (harmonic distortion) and noise do not show up as quality-degrading factors, either, the piezo pickup in principle allows for a sound recording of very high quality. Nevertheless, clearly noticeable differences compared to the radiated airborne-sound remain – this is due to the lack of the transmission filters (formed by the guitar body and neck). The piezo pickup converts the alternating force fed (perpendicularly to the guitar top) to the bridge into an electrical voltage. Conversely, the microphone converts the airborne sound radiated by the guitar top (and the neck, bottom and sides) into an electrical voltage, and therefore measures a different quantity. The latter also does have its source in the force at the bridge (amongst other forces), but depends on it via highly complicated functions.

In order to capture the differences between piezo- and microphone-recording in a practice-oriented manner, an Ovation guitar (Adamas SMT) was recorded in the anechoic chamber using a **measuring microphone** (B&K 4190), and in parallel the piezo-signal was recorded without any filtering. The free-field-equalized microphone generates an objective reference, independent of any treble boost as it is common in studio-work. There are myriad possibilities to position the microphone – not all were tried. For stage-work, often a microphone is pointed to the rear section of the guitar top, supplemented by a second microphone aiming at the neck/body-transition. Arrows mark these positions in **Fig 6.24**; in addition, the correspondingly measured 1/3$^{rd}$-octave spectra are shown (1/3$^{rd}$-octave wide filters, measured with overlap at 1/6$^{th}$-octave distance). A chord-playing guitarist activated the guitar-strings. In both spectra, we recognize a strong emphasis in the frequency range below 500 Hz; this corresponds to the auditory impression. For music productions, an equalizer would be called in to perform suitable attenuation, but for the measurements, filtering was dispensed with.

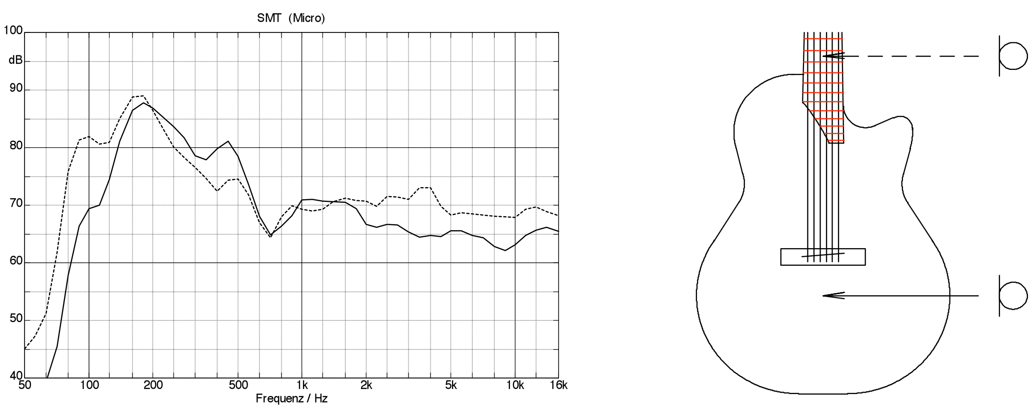


**Fig. 6.24:** Measured 1/3$^{rd}$-octave spectra (SPL re. 20 μPa) and microphone positions (at 12 cm distance). Arbitrarily fingered chords, strings struck with a pick in quick succession. "Mikro" = microphone ("mike"), "Frequenz" = frequency.

**Fig. 6.25** shows the 1/3rd-octvae spectrum of the piezo signal that is comparable to Fig. 6.24. It emphasizes the mids but is, in its even curve, well suited for further processing. The right-hand section of the figure highlights the difference between microphone- and piezo-recording: between 100 Hz and 500 Hz, resonances of the guitar top generate a strong emphasis in the microphone-spectrum, and around 700 Hz we find a minimum in the radiation which is, according to statements by manufacturers, desirable.

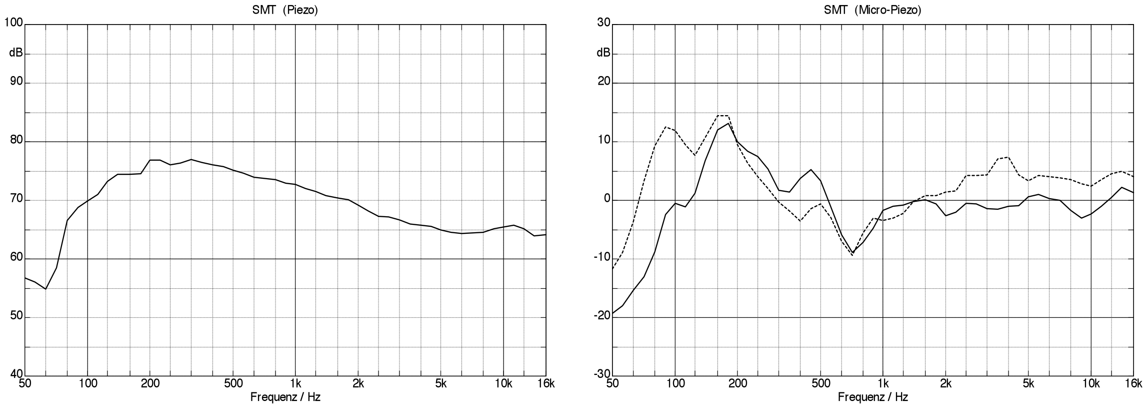


**Fig. 6.25:** 1/3rd-octave spectra of the piezo signal (left); 0 dB arbitrarily set for a curve comparable to the one in Fig. 6.24. Right: difference "mike-spectrum minus piezo-spectrum" (2 mike positions). "Micro" = mike

Differences in the 1/3rd-octave levels of ±15 dB indicate considerable differences in sound – **listening tests** immediately confirm this. However, as soon as we start to filter one of the two signals with an equalizer such that one spectrum approaches the other, the audible differences become weaker, and limit themselves to minor effects that might possibly also disappear if we could only edit the EQ-curve subtly enough. In fact, as long as we model the guitar as a linear, time-invariant system, this should indeed (better) be the case: the two transmission functions from source (string) to destination (piezo and microphone) are each describable by a fractionally rational function that an equalizer can emulate at least approximately. Non-linear effects are certainly also involved in the generation of sound – but in the investigated example, their impact obviously was rather small.

Consequently, the signals from piezo and microphone are similar to a high degree, and can be, respectively, converted into each other via (a not entirely trivial) filtering. This does not deny that significant portions of the sound energy may be fed to the neck by the nut (or the frets), and radiated there or after transmission to the guitar body – something the pickup integrated into the bridge would not sense. Still, both the sound-flux through the nut/frets and through the bridge have the string vibration as their common source, and are mathematically connected via a fractionally rational function. Conversely, the direction of the string-vibration has a more complicated effect: if a fretboard-normal 110-Hz-eigen-oscillation and a fretboard-parallel 111-Hz-eigen-oscillation jointly act onto the bridge, they might both lead to a radiation of sound. The piezo in the bridge will mainly capture the fretboard-normal component, though. In theory, one signal could again be derived from the other by filtering, but the required Q-factors of the filter stand in the way of a realization. Presumably, one of the main reasons for remaining differences is found here – but the latter are indeed weak.

**In summary:** neither the piezo-signal nor the microphone signal would be mixed down in the studio in their raw version; given suitable filtering, however, both form a good basis for further processing. Whether one chooses the piezo signal or that from the microphone, or uses a mix of both – that decision needs to be taken based on artistic reasoning.

 