Directivity of violin radiation

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Summary: The sound of a violin played by a person in an anechoic room was recorded simultaneously by 16 microphones lying in a circle with the violin in the middle (the angle among the microphone positions was 22.5°). To create the sound radiation pattern for the individual frequencies, the levels of harmonics were specified in the spectrum obtained from the SPL-recordings on the microphones in the given geometrical layout. Next, the violin was excited artificially, with the physical presence of a player standing in position as though he were playing. The manner of recording remains unchanged. Considering the results obtained from both methods of violin exciting, the widest range of angles possible was sought in which the radiation is stable.

INTRODUCTION

The directivity of the musical instruments’ radiation has been frequently studied, one of many studies being (1). As part of our project it was necessary to find a position for recording where the sound of the instrument is representative in loudness and sound timbre, and where is not crucial to precisely adjust the position of the instrument with regard to the microphone. It is possible to use an artificial driver to measure the violin’s radiation directivity, but string radiation and the influence of the violinist are not captured. A natural tone played by a violinist is not easily reproduced, hence the sound from all directions has been recorded simultaneously. The aim of this presentation is to match both methods and to determine the range of ideal microphone positions by means of a listening test.

METHOD

For a description of sound radiated by the violin sixteen microphones in an anechoic room were used. The microphones were allocated in equal proportion in a circle (the diameter of circle 3.2 m, the distance of the microphones 650 mm) situated in a plane perpendicular to the floor. The plane of the microphones passed through the middle point between the feet of the bridge. The microphone situated in the plane of the bridge in a direction opposite the top plate of the violin was labeled as 0°. Other followed anticlockwise 22.5°; 45°; ... .
Signals from the sixteen microphones were simultaneously recorded by two sound cards ARC88 (each card having eight I/O with 16 bit A/D D/A and f_α = 44.1 kHz). Recordings were made directly to a PC Pentium 133 hard disc in sixteen mono WAV files form. To excite violin sound both an artificial driver and a normal playing manner were used.
RESULTS

Artificial driver. Exciting was conducted by a Dünwalds-type driver (2) with a constant level of exiting in a 100 - 10000 Hz frequency band. A MLSSA signal (3) was used to power the driver. The recordings were treated using the MLSSA system in asynchronous mode. The frequency characteristic was calculated from a transfer function by FFT and spectral power density. The directivity indexes DI was calculated for all frequencies and from angles ($p_\theta$ ... sound pressure in a direction $\theta$ and frequency $f$).

$$DI_{9f} = 20 \log\left( \frac{p_{9f}}{\Sigma_9 p_{9f}/16} \right) \text{ [dB]}$$

The directivity index values were depicted in relation to frequencies and angles by a gray scale in graph 3D. FIGURE 1 shows the pattern of directional characteristics of the violin alone.

![Graph 1](image1.png)

![Graph 2](image2.png)
FIGURE 2 shows the same but with the physical presence of a player standing in position as though he were playing.

**Tones played by the violinist.** The professional violinist played tones g3, d4, a4, e5 in dynamic piano, mezzoforte and forte with a ‘naturale’ technique. Additionally, tones h3, f-scharp4, c-scharp5 and g-scharp5 were played in dynamic mezzoforte. The harmonic spectra of tones were calculated. The levels of each individual harmonic were used to calculate the directivity indexes for each harmonic frequency, for all three dynamics and for all tones. The directivity indexes were depicted in a graph similar to the one with the artificial driver. However, the frequency scale contains only frequencies that are in harmonic ratio to the fundamental frequency of tones in the same dynamic. Note: The frequency scale for mezzoforte is densely filled, as harmonics are issued from eight tones. FIGURE shows the pattern of directional characteristics of the violin with the tones being played by a violinist.
Next, the recordings from the sixteen microphones in the mezzoforte dynamic were sorted according to similarity with the aid of a listening test.

**DISCUSSION**

As can be seen in the preceding figures for both methods verified by the listening tests, directional radiation was dependent on the presence of the violinist, especially in the range of angles 225-270°. In the range 338-68° the tones are fairly similar in timbre. The loudness of tones increased in angle 68°, and the timbre also changed. For angles greater than 90° to 270° the perception of timbre and loudness changed notably compared with those in the rest range. Angles 112° and 315° are very similar in shine and occurrence of high frequencies. We can conclude that for the range of angles between 0 - 45° violin sound remains stable in timbre and highly similar. However, it is not possible to generalize the results until other instruments are measured.

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