Room Acoustic Scale Model Measurements using a “Spark Train”

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Introduction

The spark gap as a sound source in room acoustic scale model measurements has its pros and cons. One of the advantages is its limited size, which is particularly important for investigations at very small scales. Furthermore, a spark gap is omnidirectional [2][3] and can be constructed such that its shape has negligible effect on the sound field to be measured, for whatever scale factor. Because conventional high-frequency microphones have a very low sensitivity, a powerful spark is required to achieve a sufficiently high signal to noise ratio. However, a disadvantage of a discharge that is too powerful is the appearance of shock waves. This leads to nonlinear effects, preventing the measurement of reliable impulse responses at short distances from the spark gap [8]. A second disadvantage is the spread in the impulse levels of individual sequential discharges as a result of the changing micro-climate near the spark gap. Experiments were performed with a low-energetic spark gap (electrode distances of 1 and 8 mm). The possibility was investigated of finding a single reliable impulse response from a spark train: a rapid succession of discharges.

Definition

Spark gap

A spark gap consists of 2 electrodes, often made of tungsten wire or pencil leads [7], at a fixed distance to which a high voltage is applied. When the electrical field strength becomes sufficiently large, a breakdown of the air results in an electrical discharge. As with thunder and lightning, this coincides with a bang and a flash of light.

Spark train

A 'spark train' is defined as a rapid succession of discharges with more or less fixed intervals. This can for instance be achieved by switching electronically the primary winding of a step-up transformer (Figure 1).

Background and theory

Electric discharge

The required electrical field strength for a spark gap in air is around 3 kV/mm, mainly dependant on the electrode shape and to a lesser degree on the air pressure and relative humidity. Close to the spark discharge a shock wave is created [8] of which the strength, and therefore its sphere of influence depends on the discharge energy. For a maximum S/N-ratio with relatively insensitive microphones, the discharge energy should be as high as possible. On the other hand, in order to minimise problems with the created shock wave [1] at short distances from the source, the discharge energy needs to be as low as possible. These contradictory demands can be circumvented by using the 'Spark Train' described below.

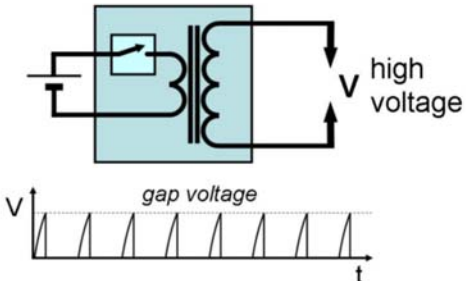

Figure 1: Principle example of a spark train generator.

Measurements

Measurement

For the measurements, a simple spark gap was used, with adjustable pointed aluminium electrodes, and a simple self-made spark generator based on the above-mentioned principle, without any special concern about signal stability and reproducibility [4]. The measurements were performed in a scale model fitted with convoluted foam to ensure that only direct sound was measured. The scale model can be considered an anechoic room. The sound was recorded using a ¼” 100 kHz microphone and a sound device providing a bandwidth of 96 kHz. The corresponding available frequency ranges in 1/1- and 1/3-octave band measurements are shown in Table 1. The measurements were performed at a temperature of about 20 ^{o}C and a relative humidity of about 50 %.

Scale factor	Max frequency [kHz]		
	1/∞ Octave	1/3 Octave	1/1 Octave
1:10	9,6	8	4
1:16	6	5	4
1:20	4,8	4	2
1:32	3	2,5	2
1:50	1,92	1,6	1

Table 1: Maximum frequency range for different scale factors using a sound device with a 96 kHz bandwidth.

The measurement set up is shown schematically in figure 2.

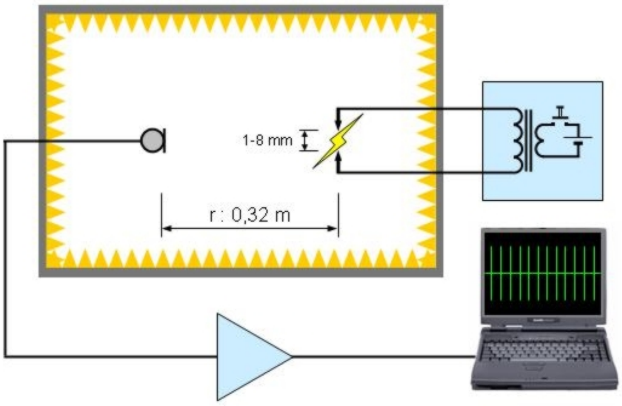

Figure 2: Scale model measurement set up.

Used spark train

Figure 3 shows an example of an Energy Time Curve (ETC-relative to $10\lg(p^2)$) of a spark measurement in the scale model of a nonreverberant room. The interval time of the signal under ambient measurement conditions, with an electrode spacing of 1 mm, had an average of 548 ms over 20 discharges, with a spread of 14 ms. With an electrode spacing of 8 mm the average interval was 604 ms with a spread of 13 ms. The source-receiver distance was 0.32 m. The spark energy was in the order of magnitude of 1 mJ.

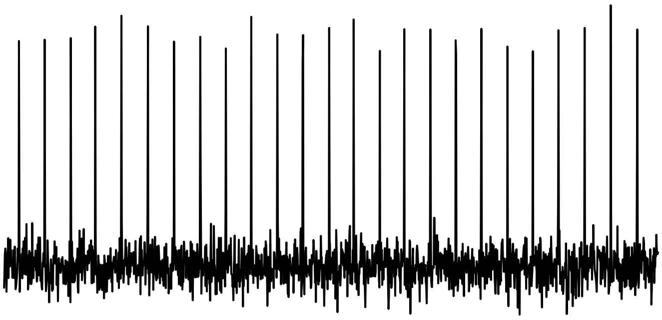

Figure 3: Typical view of an Energy Time Curve (ETC) of a spark train in a nonreverberant scale model

Measurement equipment

The measurement equipment consisted of the following components:

- *measurement room:* Scale model of anechoic room (about 0.8 x 0.8 x 0.5 m^3)
- *'spark train'- generator:* $V_{max} \approx 25$ kV, $E \approx 1$ mJ
- *sound source:* simple spark gap with adjustable spacing;
- *microphone*: 1/4" omni-directional (B&K - Type 4135, max 100 kHz);
- *input:* PCI audio device (Creative - E-MU 1212m, 24 bit, 192 kHz);
- *software:* DIRAC (B&K/Acoustics Engineering - Type 7841).

Results and Discussion

Table 2 shows the average sound level and the deviation of the mean for each octave band, over the first 20 discharges. The average interval between subsequent discharges was approximately 0.5 s, measured at a distance of 0.32 m from the spark gap.

Octave band	$L_{impulse}$ [dB] (35 ms lin)			
	Spark: 1 mm		Spark: 8 mm	
	avg	stdev	avg	stdev
1 kHz	--	--	51,7	0,16
2 kHz	51,1	0,16	61,9	0,17
4 kHz	56,4	0,15	70,7	0,15
8 kHz	59,7	0,16	77,8	0,12
16 kHz	62,9	0,25	84,5	0,11
32 kHz	74,0	0,37	73,2	0,13
64 kHz	72,2	0,38	48,5	0,12
All pass	76,2	0,36	85,7	0,12

Table 2: Average sound level over 20 subsequent discharges with corresponding spread, at a distance of 0.32 m from the spark gap.

The given sound levels are maximum values within a pulse train, measured with an integration time of 35 ms. It is clear that the spread in level over the sparks is relatively low. Statistical analysis shows that a spark train of 40 discharges will acquire an accuracy better than 0.5 dB at a confidence interval of 95%. Figures 4 and 5 show the result after separating and averaging the individual impulse responses. Both for a spark gap of 1 mm and a spark gap of 8 mm, each doubling of the number of discharges results in an increase of the INR by some 3 dB. This is in agreement with the theory.

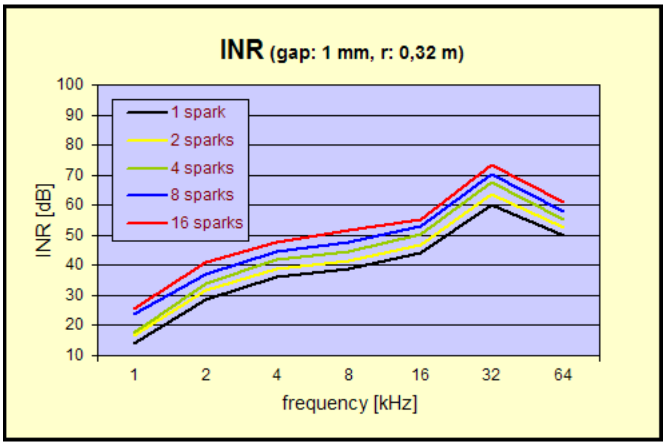

Figure 4: Improvement of the INR for each doubling of the number of 1 mm discharges as a function of the octave band frequency.

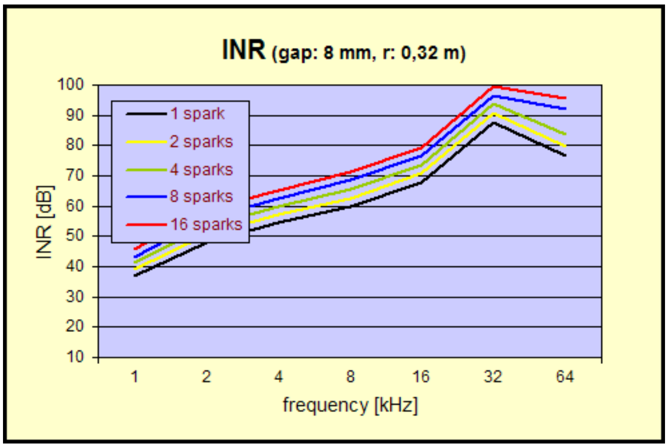

Figure 5: Improvement of the INR for each doubling of the number of 8 mm discharges as a function of the octave band frequency.

Table 3 shows the improvement of the INR for each doubling of the number of discharges, averaged over the octave bands from 1 kHz through 64 kHz.

ΔINR [dB] as a function of # discharges				
Spark gap	Number of discharges			
	2	4	8	16
1 mm	3,0	6,1	8,9	12,2
8 mm	2,9	5,7	8,5	11,3

Table 3: Improvement of the INR for each doubling of the number of discharges, averaged over the octave bands from 1 kHz through 64 kHz.

Conclusion

Using a common spark gap generating a spark train, the following conclusions can be drawn:

- Each doubling of the number of discharges gives, on average, a 3 dB improvement of the INR.
- A spark train consisting of 40 discharges is sufficient to acquire a sound level with an accuracy better than 0.5 dB at a confidence interval of 95%.
- It is possible to use a low energetic spark generator and the appropriate post-processing to acquire reliable impulse responses despite the changing micro climate near the gap. It should be noted that the post-processing should include a correction for the air absorption.

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