Design and application of linear microphone arrays

Dr.-Ing. Matthias Domke

Microtech Gefell GmbH
Structure

1. Introducing Microtech Gefell GmbH
2. Design problems regarding to the audio frequency range
3. Distribution of the microphone capsules
4. Signal processing for the microphone capsules
5. Application example: orchestra stage
6. Application example: theatre stage
7. Summary
Microtech Gefell GmbH

founded in 1928 by Georg Neumann in Berlin

moved to Gefell during the world war II
*Georg Neumann & Co*

under the communist regime the name changed to
*VEB Mikrofontechnik Gefell*

the new name after German Reunion is
*Microtech Gefell GmbH*

with a long tradition in development
and manufacturing of studio and
measurement microphones

General Manager: Dr.-Ing. M. Domke
Owner: Georg Neumann KG

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Product range

studio microphones

measurement microphones
Problem: wide range of the wavelength

<table>
<thead>
<tr>
<th>frequency</th>
<th>wavelength</th>
<th>array length</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Hz</td>
<td>3,400 m</td>
<td>1,700 m</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>0,340 m</td>
<td>0,170 m</td>
</tr>
<tr>
<td>10000 Hz</td>
<td>0,034 m</td>
<td>0,017 m</td>
</tr>
</tbody>
</table>

- a long line array is necessary for the low frequency directivity
- a small transducer distance is necessary for reduced grating lobes at high frequencies  
  at low frequencies the transducer density is too high and the sample distance is unnecessarily low
- the directivity increases when the frequency increases  
  the directivity at high frequencies is much too high
- constant relationship between the array length and the wavelength  
  the array length must decrease if the frequency increases
- constant relationship between the sample distance and the wavelength  
  (reduced transducer density in the low frequency part of the array)
Distribution of the microphone capsules

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Disadvantage:
• very high number of microphone capsules and processing channels

Advantage
• very low number of microphone capsules and processing channels

Disadvantage
• wide vertical coverage angle

Advantages
• low number of microphone capsules and processing channels
• narrow vertical coverage angle
Constructions

KEM 975
8 microphone capsules
4 equidistantly spaced microphone capsules (25 mm)
array length = 300 mm
\( f_{gu} = 570 \, \text{Hz} \)
analog signal processing
no latency
beamsteering not possible

R-ZeMiS 12
12 microphone capsules
4 equidistantly spaced microphone capsules (25 mm)
array length = 1200 mm
\( f_{gu} = 145 \, \text{Hz} \)
digital signal processing
4,2 ms latency
beamsteering possible
Summation of the capsules - Beamforming

without filter  with FIR filter

without filter  with FIR filter
Transfer functions of the FIR-filters

capsule 1/-1
capsule 2/-2
capsule 3/-3

capsule 4/-4
capsule 5/-5
capsule 6/-6

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Beam steering with delays
Signal processing – filter, delay and sum
Application of the KEM 975: orchestra stage
Problems when recording an orchestra stage

- unequal distribution of the recording level with an increasing distance between the microphone and the sound source (instrument)
- soundfield at the microphone position is influenced by reflections from the walls and the ceiling of the stage

Problems with additional microphones very close to an instrument
- a compensation of level and delay is necessary
- such microphones are not invisible
- some instruments have a multi directional and frequency dependent radiation of sound

The microphone for the recording of an orchestra should
- be in the far field of the orchestra
- have an equal distribution of the recording level from the nearest to the farthest instrument position
- have enough directivity to reduce the reflections from the walls and the ceiling of the orchestra stage
Level distribution on the stage

Stage dimensions: (10 x 10) m
Microphone height: 3 m

The distribution of the recording level on the orchestra stage is more equal with the microphone array KEM 975 in comparison with a conventional microphone with cardioid polar pattern.
Applications with single and multiple beams
Orchestra stage
Beamsteering on the Orchestra stage

Stage dimensions: (12 x 11) m
Microphone placement: 4 m / -35°
Recording angle: 30°
Beam combination on the orchestra stage

R-ZeMiS 12 (digital)
Beam_{-20\degree} \times 0,5 + Beam_{20\degree}

ORTF stereo microphone with cardioid capsules

very equal distribution of the recording level on the orchestra stage from the nearest to the farthest instrument position with the linear microphone array
Theatre stage

Comparison between different microphone solutions for sound reinforcement and a reverberant enhancement system

- **KEM 975 (analog)**
- **Shotgun**
- **Cardioid**

**Stage dimensions:** (10 x 15) m

**Recording distance:** 10 m

**Microphone placement:** 3 m / -10°

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Beamsteering on the theatre stage

Microphone model: R-ZeMiS 12 (digital)
Microphone placement: 6 m / -35°
Recording angle: 30°

very equal distribution of the recording level on the theatre stage from the nearest to the fairest actor position with the linear microphone array

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Summary

1. a constant relationship between the sample distance and the wavelength reduces the number of necessary capsules

2. a constant relationship between the array length and the wavelength leads to a frequency independent directivity

3. with beamsteering by delays certain parts of a stage can be covered

4. by combining single beams with adjusted levels a main beam can be created with a sensitivity adapted to the distance

5. this results in a controllable and very equal distribution of the recording level on the stage
Thank you for your attention