Project: ME2440 Fundamentals of Vibrations and Acoustics
Due: Friday, December 17, 2021 at 5:00.

Microphone Array Design

The project should be your independent work. You can of course use references and solicit my help, but you should present theory in your own words and cite sources that you used, especially in cases where you may have copied an image for illustration. While you may wish to use the array processing toolbox to check your design, **you must write your own MATLAB code to perform the array analysis and plot the directivity plots that are submitted**. Keep in mind, you may wish to investigate geometries other[i,ii] than what we've directly covered (mostly line arrays).

The requirements for the acoustic microphone array are as follows:

- Steerable in 3D space a full 360 degrees in azimuth, while meeting the additional requirements below within the range of [-45, 45] degrees in elevation
- Operate between 5-10 kHz (meet the specs below)
- Include the directivity of a cardioid microphones, with a directional factor given by:
$$H(\theta) = 0.5(1 - \cos(\theta))$$
- Has a Main sidelobe width of 40 degrees or less, when steered to 45 degrees, azimuth
- Maximum sidelobe level (MSL) of 20 dB or more.
- Has a baffle installed behind the array (how does this affect the array pattern?)
- With the minimum number of mics that achieve the design requirements of the array (in order to contain costs)

You may choose any array geometry (see B&K handout) as long as it meets the requirements above and has no grating lobes. You are permitted to use window function (See B&K reference) if you choose.

Submit a report **and** your actual Matlab script(s) (as .m files). The report should be nicely type-written using Word, LaTeX, or similar and contain:

1. The design requirement given above (you can also reference this assignment statement)
2. A theory section having
    a. A defined coordinate system
    b. All of the required equations used to get the beam pattern for your baffled array
    c. Whether you employed additional tools from a standard delay-and-sum beam, such as windowing or filter and sum (not covered in class)
3. Results:
    a. Present the chosen array geometry (plot of the array, dimensions, number of mics, mic spacing, value for kd)
    b. Present Polar and rectangular plots of the beam pattern for your final design, including annotations on the rectangular plot showing that the design requirements were met
        i. Polar plots at [0, 15, 30, and 45] degrees
        ii. Rectangular plots at [0, 15, 30, and 45] degrees
4. Discussion: Referring back to the Results section, discuss the performance of your design, rationale in choosing your design, the iteration process, any difficulties that you had in achieving the goals, anything that you learned that was particularly interesting, etc.
5. References

i. Zaverri, HS, Bruel & Kjaer Technical Review: Beamforming, Bruel & Kjaer, No. 1, 2004.
ii. CC Lai, YH Leung, SE Nordholm, *A Study into the Design of Steerable Microphone Arrays*, Springer, 2017
iii. LE Kinsler, AR Frey, AB Coppens, JV Sanders, *Fundamentals of Acoustics*, 4/e, John Wiley & Sons, NYC, 2000.