

# *Multiple Chamber Aligned in Parallel Cavity Resonator (MCAP-CR)*

## **Basic Concepts**

*Advanced Loudspeaker Enclosure*

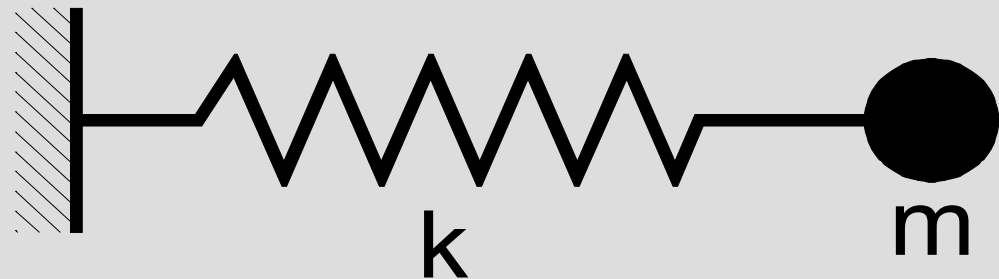
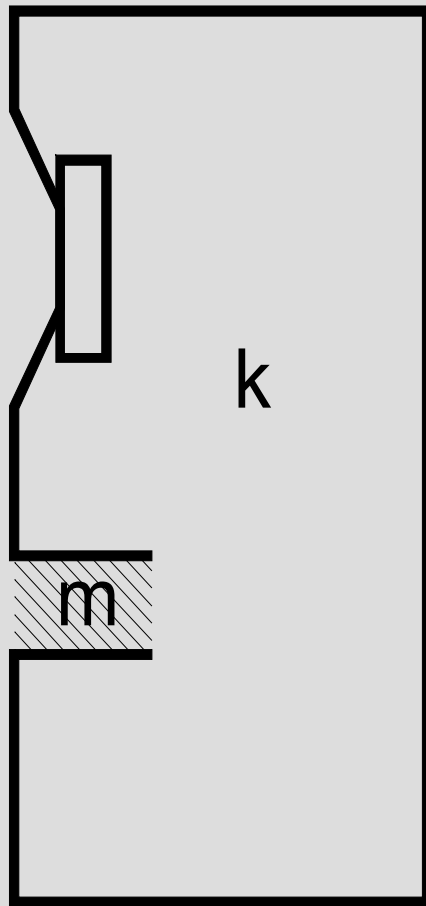
**By Shigeru Suzuki**

**March 23, 2008**

**Revised in November 8, 2008\***

**\* MCAPSS was renamed as MCAP-CR**

# *Traditional Approaches Bass-Reflex Architecture*



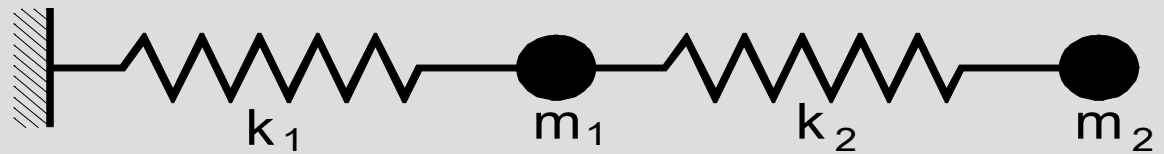
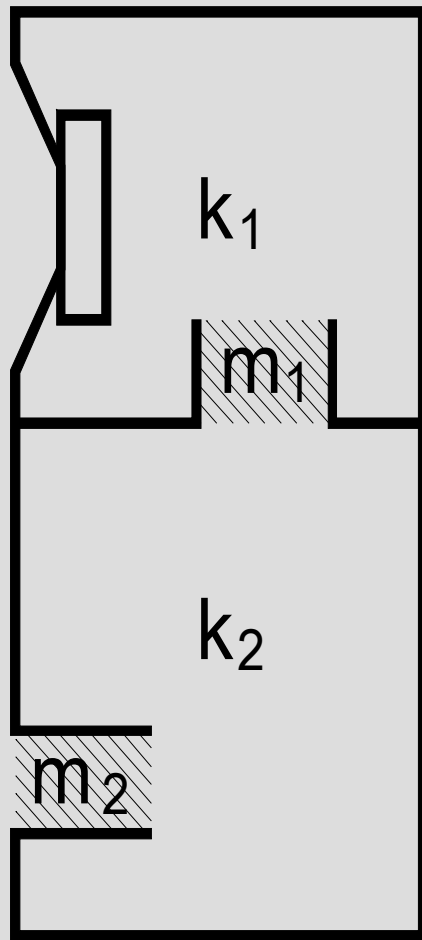
*Single Bass Reflex system has just ONE  
Characteristic Frequency*

$$f_D = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

Bass-reflex architecture is an application of Helmholtz's cavity resonator

# Traditional Approaches

## Double-Bass-Reflex Architecture



**Double Bass Reflex system has TWO Characteristic Frequencies.**

$$f_D = \frac{1}{2\pi} \sqrt{\frac{k_{11}m_2 + k_{22}m_1 \pm \sqrt{(k_{11}m_2 + k_{22}m_1)^2 - 4m_1m_2(k_{11}k_{22} - k_{12}k_{21})}}{2m_1m_2}}$$

See Appendix-A of "Equations to calculate characteristic frequencies of Multiple Chamber Aligned Cavity Resonator (MCAP-CR)" by Shigeru Suzuki.

# *Technical Target of MCAP-CR*

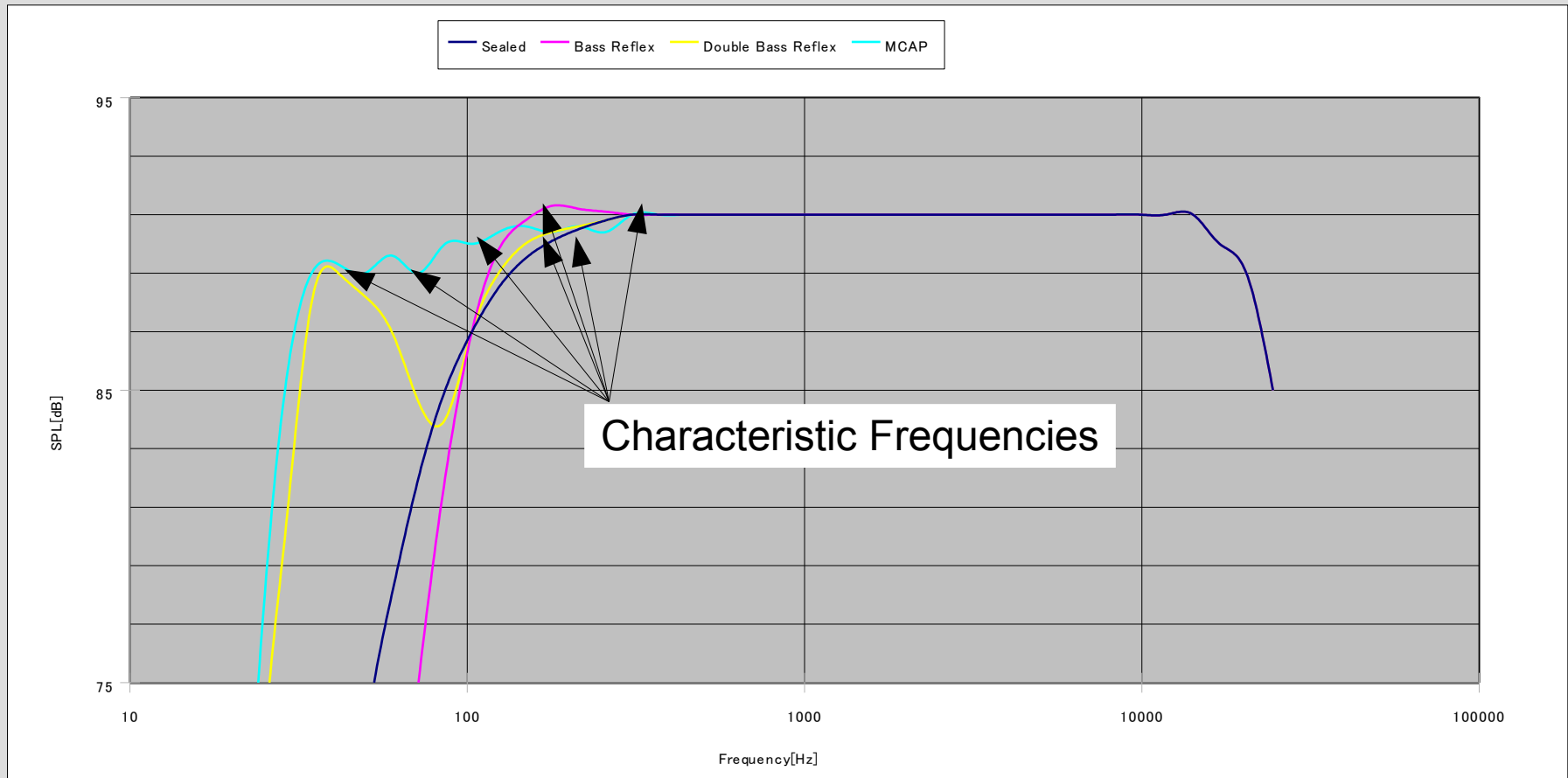
- Improve frequency response over low range (below  $f_0$  of speaker unit)
- Let this architecture suitable not only for woofer drivers but also for full-range speaker drivers.
- Make Speaker Enclosure size smaller as much as possible compared with existing equivalent systems.
- Develop calculation method so that everyone could design one's own.

# *Advantages of MCAP-CR*

- MCAP-CR architecture has multiple characteristic frequency. The number of characteristic frequencies is theoretically unlimited.
- MCAP-CR architecture generates lower frequency than  $f_0$  at considerably high sound pressure level.
- MCAP-CR architecture requires smaller enclosure than existing equivalent systems.
- MCAP-CR is not only suitable for woofer drivers but also full-range drivers . Full-range drivers are free from electrical network circuits so that they are advantageous.

# Frequency Response

## MCAP-CR vs. Traditional Approaches



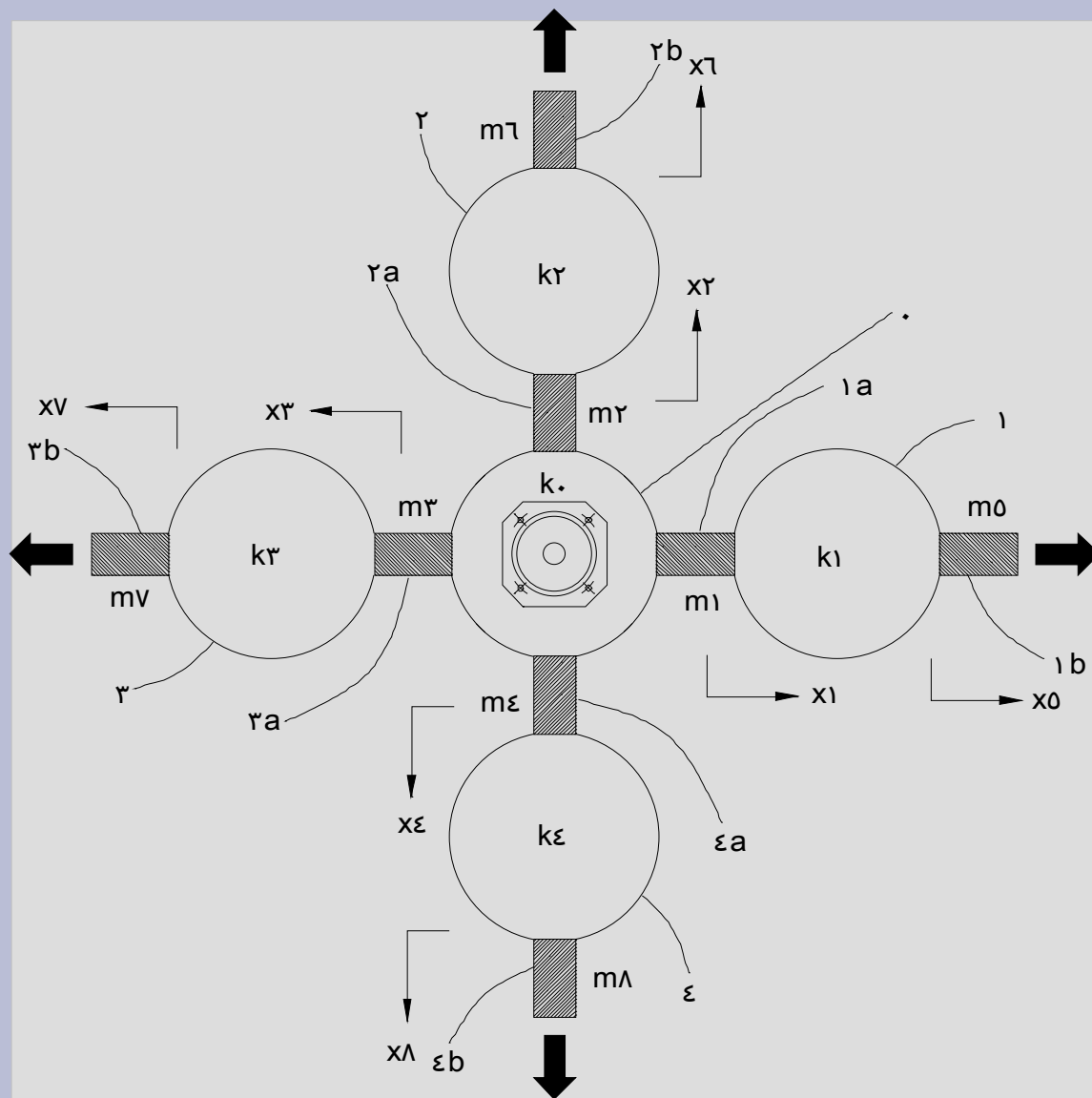
MCAP-CR has 4 or more characteristic frequencies (depends on number of chambers and ducts), while double-bass-reflex has 2 and single-bass-reflex has one. Multiple characteristic frequency realizes improved response in low frequently region.  
*Note: This is just conceptual figure to explain difference among different systems.*

# *Technical Feature of MCAP-CR*

- MCAP-CR stands for *Multiple-Chamber Aligned in Parallel Cavity Resonator.*
- MCAP-CR is designed to boost multiple-characteristic frequency.
- MCAP-CR consists of main chamber where speaker driver is installed, sub-chambers, and ducts.
- Each sub-chamber is connected to main chamber through inter-chamber duct.
- Some of (typically, all) sub-chambers have open-air duct.

# How MCAP-CR works

## Schematic: Number of Sub chambers=4



0: Main chamber  
1-4 : Sub-chamber

$m_1 - m_8$ : mass of air that is involved in each duct

$k_0$  : reference spring constant for speaker cone

$k_1 - k_4$  : equivalent spring constant for each duct

$x_1 - x_8$  : displacement of mass of air

Note: Number of sub-chambers is theoretically unlimited.

If number of sub-chambers is one, it is identical to traditional double-bass-reflex architecture.



# Equations of Motion of MCAP-CR

## Equations of Motion : Free Vibration

$$\left\{ \begin{array}{l} m_j \ddot{x}_j + k_0 r_j \sum_{i=1}^N r_i x_i + k_j r_j (r_j x_j - r_{j+N} x_{j+N}) = \cdot \\ m_{j+N} \ddot{x}_{j+N} + k_j r_j (r_{j+N} x_{j+N} - r_j x_j) = \cdot \end{array} \right.$$

$m_j$ : mass of air involved in each duct

$N$ : number of sub-chambers

$k_0$ : reference spring constant of base chamber

$k_1$ - $k_N$  : spring constant of each sub chamber for reference cross-sectional area

$r_j$  : ratio of cross sectional area divided by reference area

$x_j$  : displacement of air mass in each duct

# *Equation of Motion: Matrix Form*

Equation of motion of free vibration can be expressed in matrix form.

$$\mathbf{M}\ddot{\mathbf{X}} + \mathbf{K}\mathbf{X} = \mathbf{0}$$

M: Mass Matrix

K: Stiffness Matrix

X: Displacement Vector

Eigen Value Problem

$$|\mathbf{K} - \lambda \mathbf{M}| = 0$$

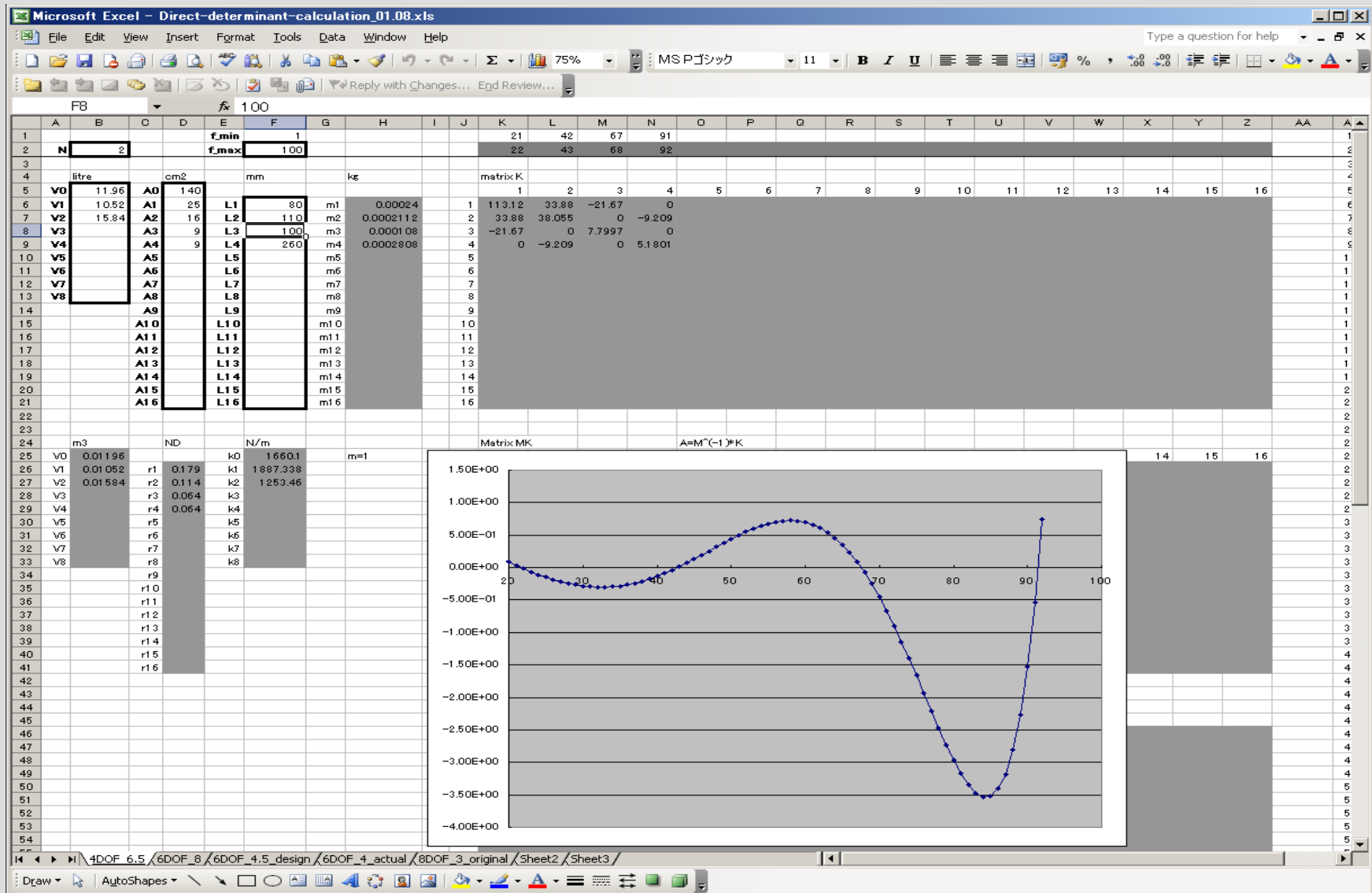
$\lambda$  : Eigen Value

# *Solving Equations of MCAP-CR*

*Refer to another document*

1. Determine number of sub-chambers
2. Determine principal dimensions (size of chambers, ducts)
3. Develop equations of motion of your model
4. Calculate mass-matrix and stiffness-matrix
5. Solve Eigen Value Problem using a computer program (described in another document).

# Solving Equations of MCAP-CR Calculation Window (Example)



# *Expected Q & A (1)*

## *General*

### **QUESTIONS**

### **ANSWERS**

- Do I like MCAP-CR sound?
  - *It is recommended for those who like full-range system's sounds, but not recommended for those who prefer multiple-way systems rather than full-range systems.*
- Is designing MCAP-CR difficult for me?
  - *It may be difficult if you are not good at mathematics. Knowledge level of MS in Engineering may be required.*
- Do you have examples of MCAP-CR?
  - *Yes. I have already made six models. Some of them will be uploaded to this web page.*
- Is MCAP-CR good for high fidelity system?
  - *I believe YES. One advantage of MCAP-CR is it is good for full-range drivers.*
- Is it difficult to assemble MCAP-CR?
  - *It may be difficult for beginners.*

# *Expected Q & A (2)*

## *General*

### **QUESTIONS**

### **ANSWERS**

- I have difficulty to calculate and design MCAP-CR. May I ask you for more details?
- Where can I buy MCAP-CR?
- Where can I hear sound of MCAP-CR?
- Do I need to pay for the patent.
- *Yes, I would try to help you as much as possible. Please do not hesitate to contact me.*
- *Any MCAP-CR is not sold right now. There is no manufacturer. I wish I could, but I have no fund to found a company.*
- *There is nowhere you can hear sound of MCAP-CR except my home. You may write to me if you really want to hear them. My home is located in Tokyo, Japan.*
- *Patent application was submitted in 2007, but it has not yet become a right. Even though patented, it does not affect non-commercial personal use.*

# Expected Q & A (3)

## Technical

### QUESTIONS

### ANSWERS

- What is the recommended number of sub-chambers?
  - What characteristic frequency should be targeted?
  - How can I determine size of ducts and volume of each chamber?
- *It must be at least 2.  $N=2, 3,$  or 4 will be suitable for practical reasons.*
  - *From my experience, lowest characteristic frequency should be 50Hz for 3" drivers, 40Hz for 4" drivers, and 20Hz – 30Hz for 6.5" and bigger drivers. Highest characteristic frequency may be determined based on driver's response curve.*
  - *You may begin with defining volume of chambers. Chamber's size depends on practical constraint. I suggest that summation of cross sectional area of each inter-chamber duct does not exceed  $\frac{1}{2}$  of driver's effective area ( $a_0$ ). Cross sectional area of open-air duct should be equal or even smaller than of inter-chamber duct. Then calculate characteristic frequencies. Parameter should be lengths of ducts.*

# Expected Q & A (4)

## Technical

### QUESTIONS

### ANSWERS

- Response in low frequency region seems not enough. What can I do?
  - Which drivers should be suitable for MCAP-CR?
- *MCAP-CR generates lowest characteristic frequency, so you may boost low frequency using tone control. Bass-reflex system cannot boost lower than  $f_D$ ; it is true to MCASPS, but MCAP-CR has lower  $f_D$ , thus using tone control is very effective.*
  - *Considerably powerful full-range drives are recommended. I suggest 3" drivers of Tangband: W3-316 is most recommended. If you like Fostex, I suggest FE126E, FE166E, FE206E, FF125K, FF165K, and FF225K; however, any driver can be used as you prefer.*



# *Expected Q & A (5)*

## *Technical*

### **QUESTIONS**

### **ANSWERS**

- May I think that MCAP-CR is compete technology?
  - How can you complete MCAP-CR technology?
- *MCAP-CR is proven technology, yet it is not complete. Any technology is NOT perfect. We have to improve applications everyday.*
  - *I will try to design, assemble and test as many models as possible, but cannot make enough. I would be the most happy, if you want to work with me to help developing MCAP-CR. One purpose of publishing this document is to find a partner. My contact email address is shown in the web page.*

# Summary

- *MCAP-CR is an application of cavity resonator Cavity Resonator with multiple characteristic frequency.*
- *Equations and solution were proposed.*
- *MCAP-CR is suitable not only for woofer drivers but also full-range drivers.*
- *I would be the most happy if you become interested in MCAPO-CR. - Thank you.*