Master Thesis

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an der

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Thema:

Investigation of resonant modes on the chassis of handheld wireless terminals

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Outline

- Introduction
- Chassis radiation
- Software package NEC-2
- Macro pre –and postprocessor for NEC-2
- Application to a simple board
- Convergence of the method used
- Comparison against numerical reference example
- Numerical results
- Conclusion

Introduction(1)

- An antenna can be defined as any structure that can radiate electromagnetic wave into a medium.
- Small antenna are found in all personal radio communication devices.
- Today, mobile phones are one of the best selling electronic devices on the market.
- The performance of the antenna depends on the antenna and the phone chassis.
- During the last years the chassis effect has been investigated in several good publications.
- According to the published results, the power radiated by a typical self resonant antenna element, at E-GSM 900 frequencies is less than 10% of the total radiated power!!
- 90% of the power is radiated by a dipole type current distribution of the mobile terminal chassis.

Introduction (2)

- This work proposes to find the chassis resonances by using a generic exciter with frequency independent behaviour, i.e a plane wave excitation
- The objective of this work is to find the resonant modes of common mobile phone form factors (e.g bar type, folder type), their dependence on geometrical parameters and to indentify options for tuning

Chassis radiation (1)

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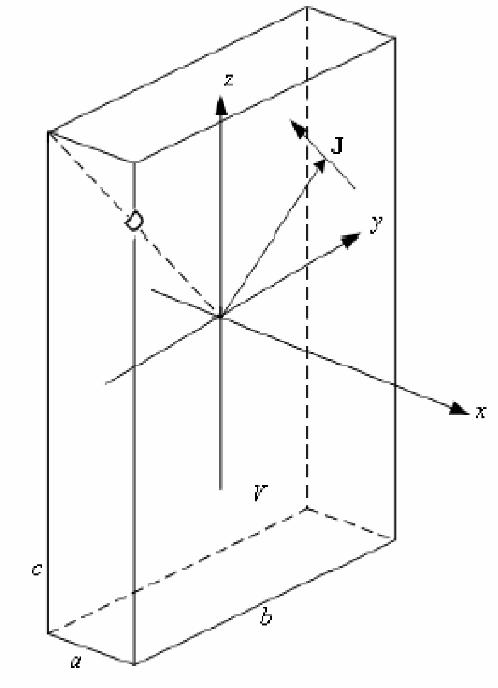
- The radiation is the process of emiting energy from the source
- In the case of mobile phones, the main radiation is due to the movement of free charges along its chassis
- The process is described by the current density vector
- The radiation vector depends on the current density and describes the total current distribution on a given phone chassis
- The resonance frequency of a mobile phone chassis occurs when the radiated power density which depends on the radiation vector is maximum

$$\mathbf{E} = -\mathrm{j}\, k_0 \eta \frac{\mathrm{e}^{-\mathrm{j}k_0 r}}{4\pi r} \mathrm{e_r} \times \left(\mathrm{e_r} \times \mathbf{F}(\mathrm{k})\right)$$

$$\mathbf{H} = -\mathrm{j}\, k_0 \frac{\mathrm{e}^{-\mathrm{j}k_0 r}}{4\pi r} \left(\mathrm{e_r} \times \mathbf{F}(\mathrm{k})\right)$$



$$\mathrm{P_{av}} = \frac{1}{2}\mathrm{Re}\{\mathbf{E} \times \mathbf{H}^*\}$$

$$\mathbf{F}(\mathrm{k}) = \int_{\mathrm{r}' \in V} \mathbf{J}(\mathrm{r}')\, \mathrm{e}^{\mathrm{j}\mathbf{k}\mathrm{r}'}\, \mathrm{d}V.$$

$$S(\mathrm{k}) = \mathrm{e_r} \cdot \mathrm{P_{av}} = \frac{\eta}{32\pi^2 r^2} \left|\mathrm{k} \times \mathrm{F}(\mathrm{k})\right|^2.$$

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Chassis radiation (2)

- A simplified description of the current density field can be used to predict the far field radiation from an electrical small object such as a phone chassis
- The far field is then dominated by the first and second moment of the radiation vector
- The first moment can be described by

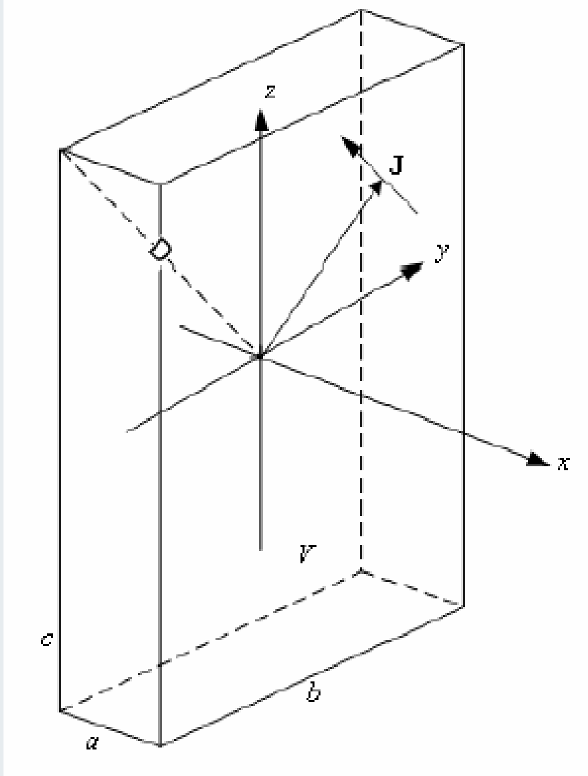
$$\mathbf{F}_0 = \int_{\mathbf{r}' \in V} \mathbf{J}(\mathbf{r}')\,\mathrm{d}V = -j\omega\mathbf{p}$$

- The second moment is made up by the magnetic dipole moment and the quadripole moment
- The magnetic dipole moment is described by

$$\mathbf{m} = \frac{1}{2}\int_{\mathbf{r}' \in V} \mathbf{r}' \times \mathbf{J}(\mathbf{r}')\,\mathrm{d}V$$

Chassis radiation (3)

- The radiation properties of the chassis include the resonance frequency and the quality factor
- The method used to find the resonance frequency is based on the evaluation of the maximum of $\mathbf{F}_0$
- A frequency variable plane wave travels along the +x axis and the polarization of the electric field is along the +z axis

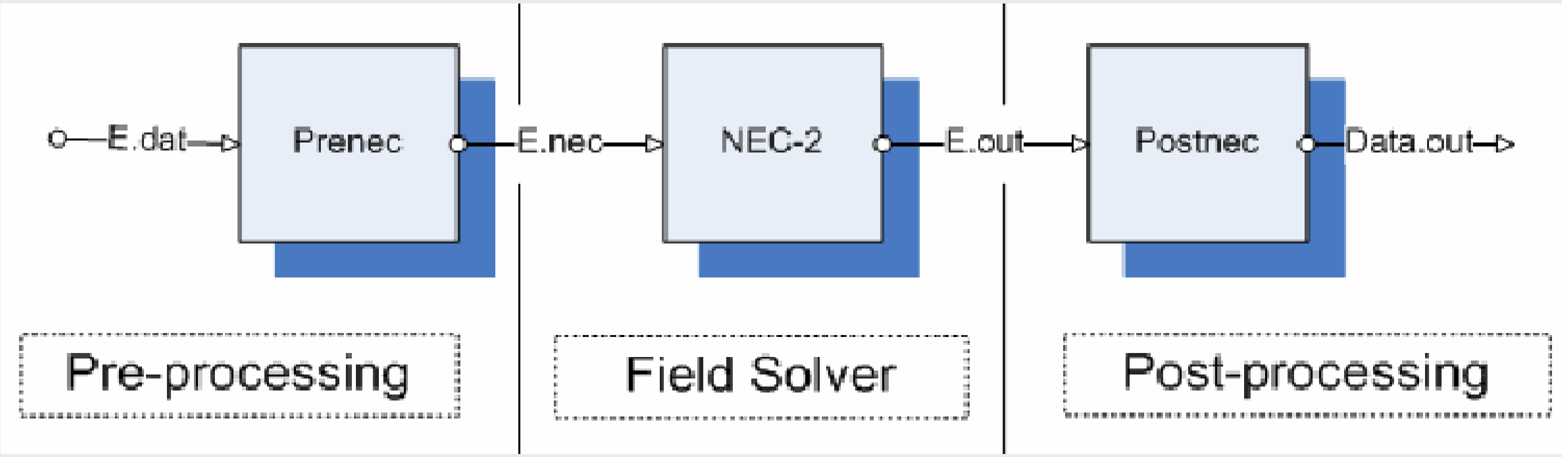


Software Package NEC-2

- Several free and commercial software packages can be used for em fields analysis (EMAP5, NEC-2, IE3D, ANSOFT...).
- These packages uses numerical methods such as FD, FEM, MOM, FDTD, ...
- In In this work, NEC-2 which is based on the MOM has been chosen.
- NEC-2 is free and easy to use in comparison to most commercial software packages
- NEC-2 is easy to use with script programming and the full control of segmentation is possible
- The full code of NEC-2 is available and can be modified without any restriction.

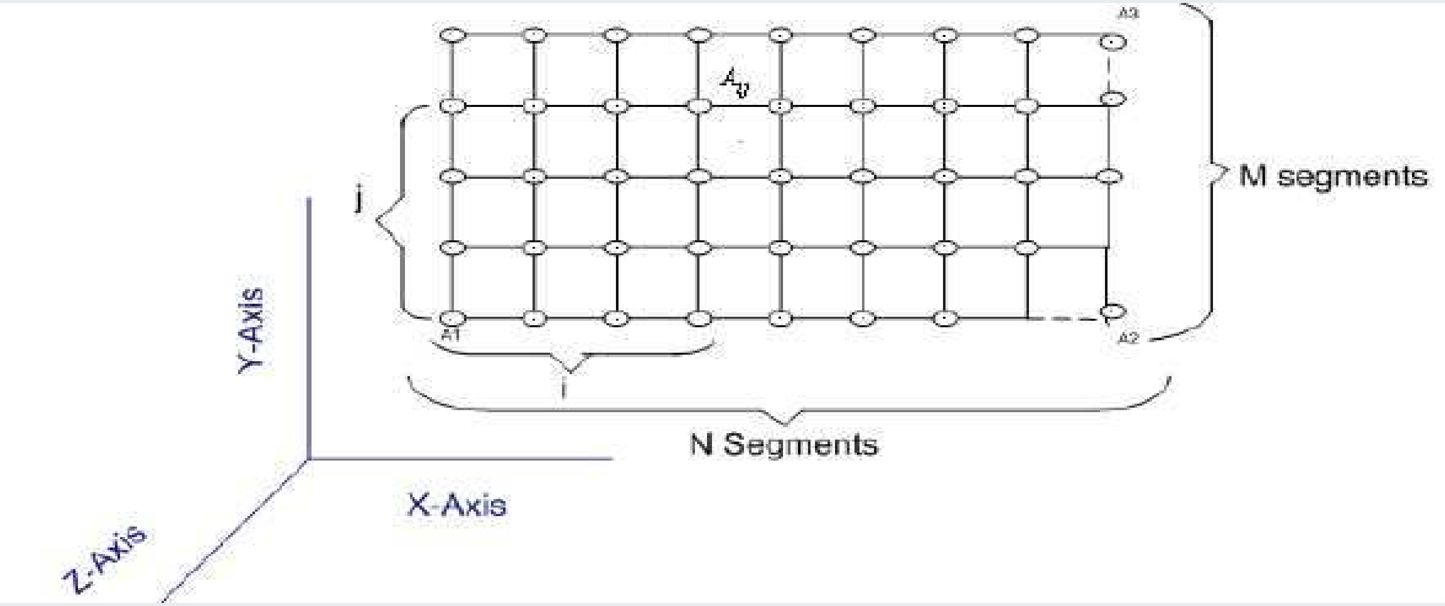
Macro pre- and postprocessor for NEC-2 (1)

- Input data of NEC-2 are numerical
- Typing the input of each structure is difficult and almost impossible with hands
- A pre-processor was developed to generate input data and is called Prenec
- For the analysis of the output data, a postprocessor was developed and is called postnec



Macro pre- and postprocessor for NEC-2 (2)

- The structures considered here are rectangular
- A rectangular grid macro with which allows for a variable number of segments has been developed

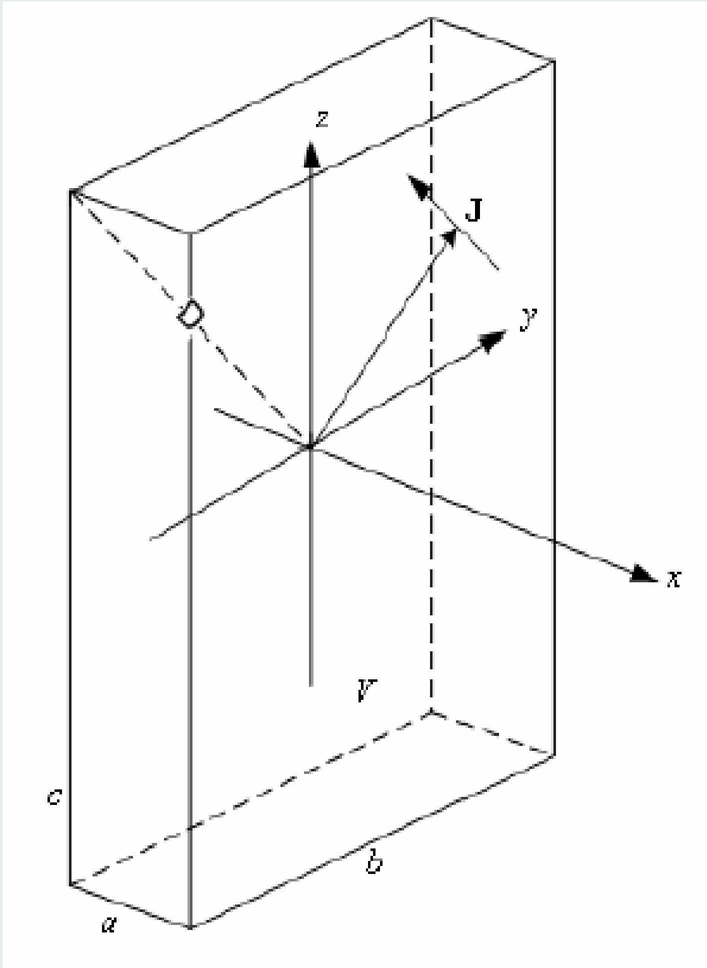


$$\mathbf{r}_{ij} = \mathbf{a}_{10} + i \cdot \frac{\mathbf{a}_{21}}{N} + j \cdot \frac{\mathbf{a}_{32}}{M}$$

Macro pre- and postprocessor for NEC-2 (3)

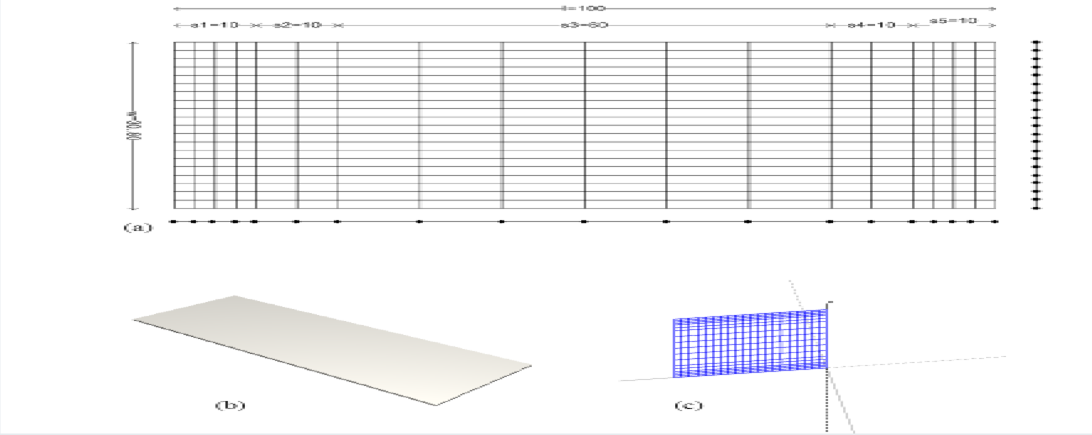
- The NEC-2 postprocessor is based on the computation of the magnitude of the first moment of the radiation vector along the z-axis.

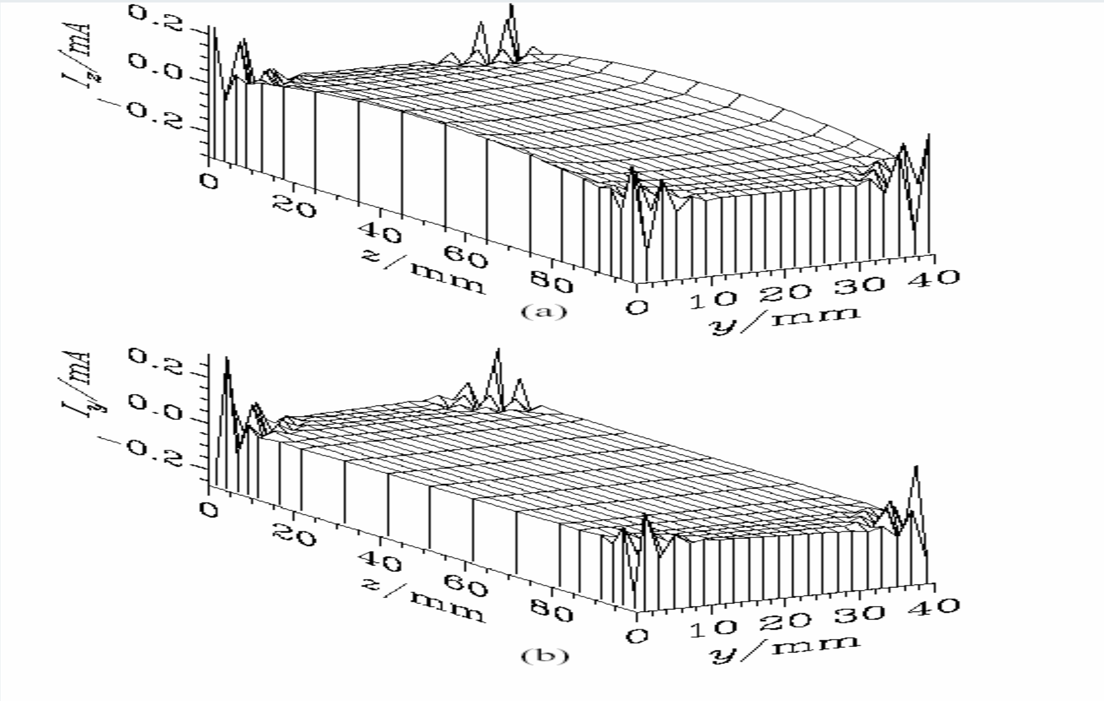
- The resonance frequency of the chassis is given when the magnitude of the first moment of the radiation vector along the z-axis is maximum



Application to a simple board (1)

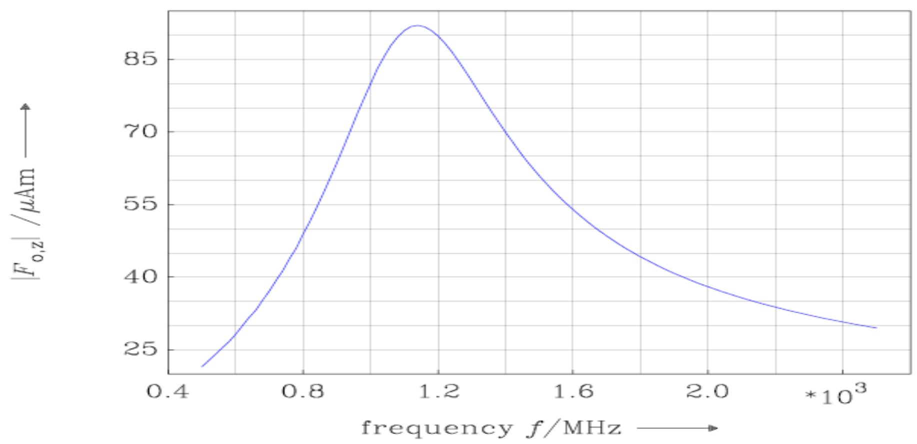
- A simple board a board of length 100 mm and width from 30 to 80 mm, in steps of 10 mm
- First a board of width 40 mm is considered
- Exciting the board with a frequency of 1170 MHz and considering a z-polarized plane wave excitation, an example of the current density distribution along the y and the z-axis on the right side
- The board is now excited with different frequencies from 500 to 2500 MHz, in steps of 20 MHz





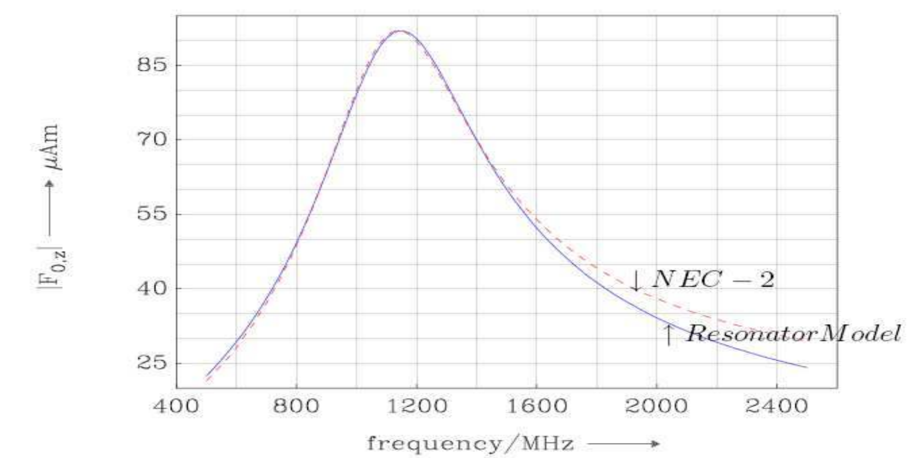
Application to a simple board (2)

- For each frequency, the corresponding $|\mathbf{e}_z \mathbf{F}_0|$ along the z-axis is computed
- Considering now that the width of the board takes the values from 30 to 80 mm, in steps of 10 mm
- The same procedure can be applied
- Time needed too long because one has for each board to simulate 101 frequencies points
- In order to obtain the result quickly, a resonator model was developed.



$$\mathbf{e}_z \mathbf{F}_0 \approx \frac{A}{1 + \mathrm{j}Q(\frac{f}{f_0} - \frac{f_0}{f})}$$

$$f_{\max} = \frac{Q}{\sqrt{Q^2 - \frac{1}{2}}} f_0.$$



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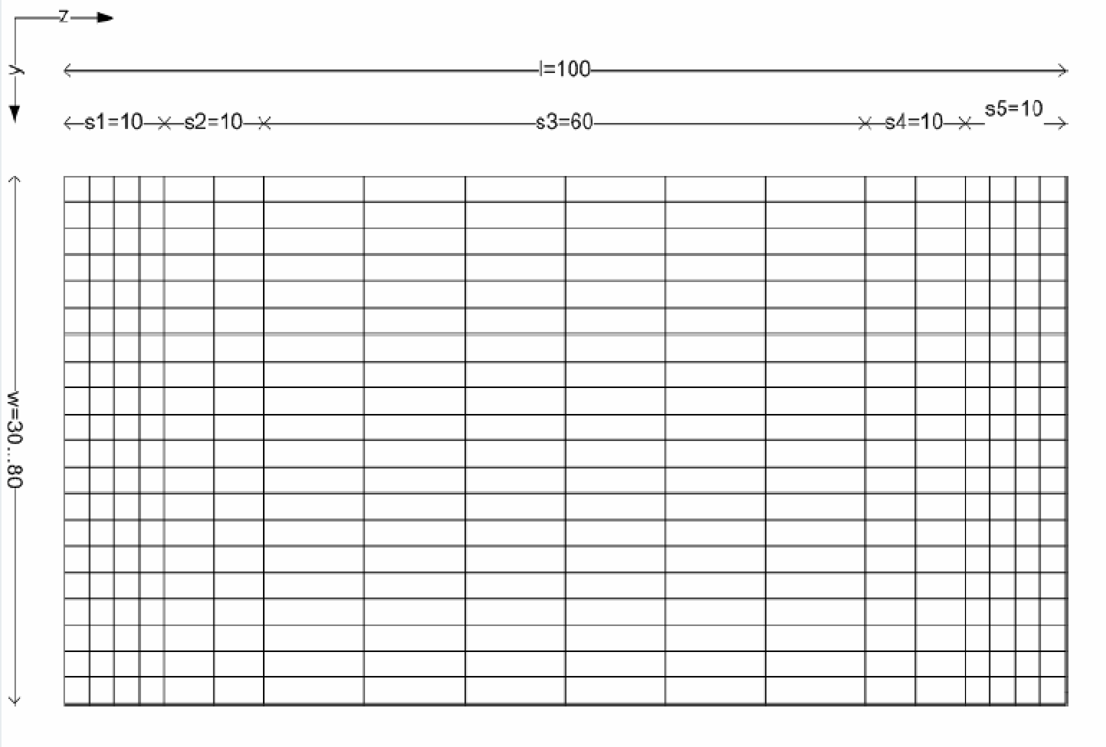
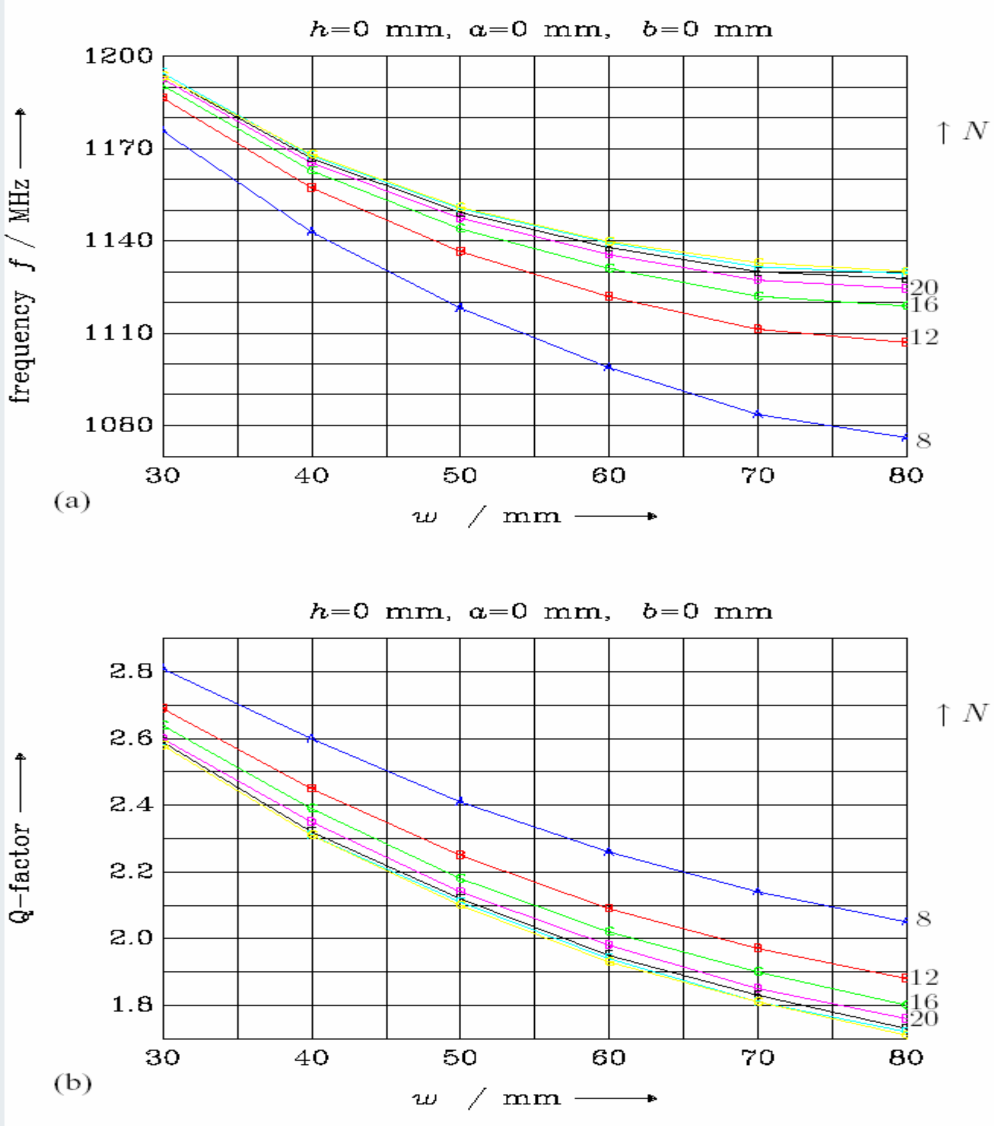
Convergence of the method used (1)

- Convergence testing is the process of increasing of segments in each wire of a model until the program output values change by only insignificant amount relative to the purpose of modeling
- The convergence testing was made for a simple board of length 100 mm and a variable width in the range from 30 to 80 mm, in steps of 10 mm
- It is made by increasing on the y-axis the number of segments from 8 to 32, in steps of 4.



Convergence of the method used (2)

- **For each variation of the segments number, a curve is displayed representing on the abcissa the width of the board and on the ordinate the resonance frequency and the quality factor corresponding.**
- **When increasing the number of segments, the curves are coming closer each other.**
- **When the number of segments is greater oder equal to 20, there is no more significant change.**



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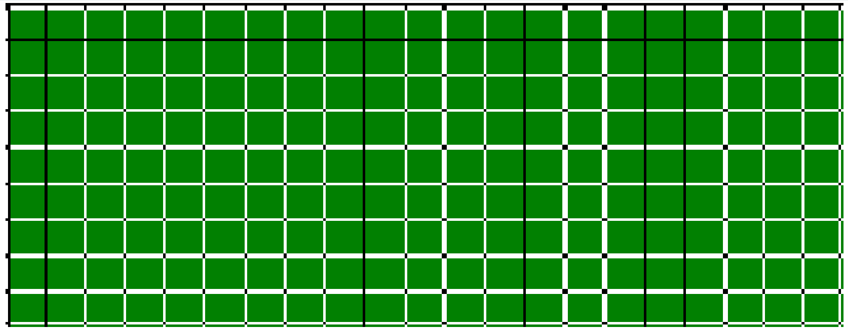
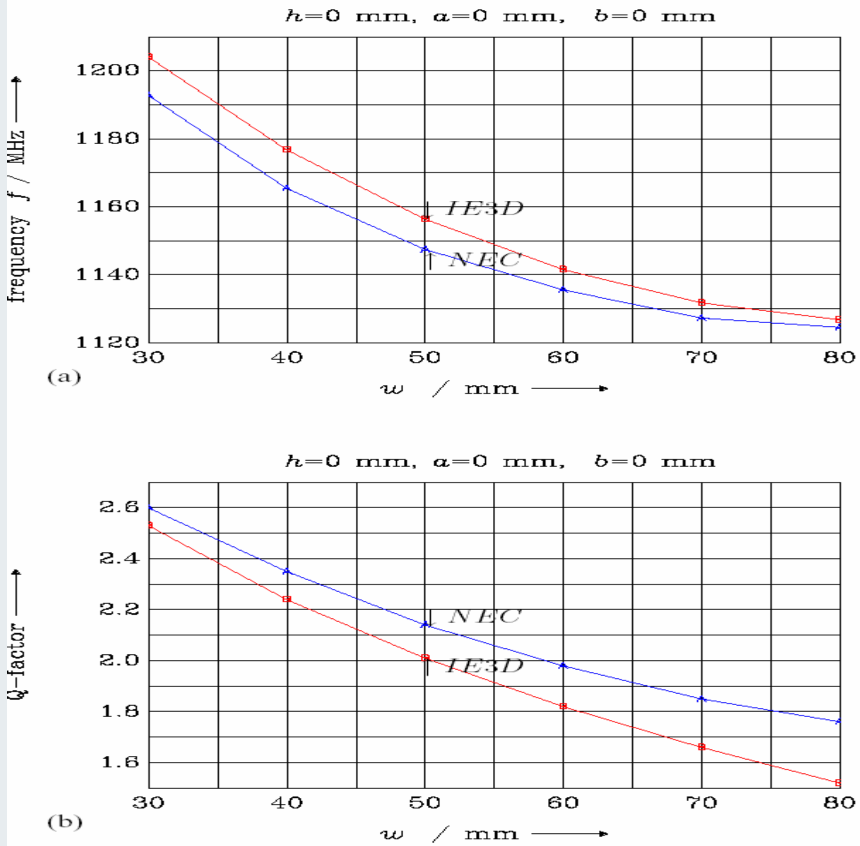
Comparison against numerical reference example

- NEC-2 has been used so far for simulations
- To verify the results obtained from NEC-2, the resonance frequency and the quality factor dependence on the width of the board was plotted using IE3D
- The curves obtained from the two software packages (NEC-2 and IE3D) are displayed in the same graph
- It can be noticed that when considering the resonance frequency, the deviation is less thhan 1%
- When considering the quality factor, the deviation is about 8%.
- This is due to the fact that the two software packages are different.
- The discretization methods used are also different.





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Numerical results for selected structures (1)

Bar-type phones

- For all simulations considering bar-types chassis, the same number of segments was used for each model
- The length of the board was maintained constant to 100 mm
- The other geometrical parameters a, b, h, w are variable and are used depending on the structure
- The Physical parameters are the resonance frequency and the quality factor
- The aim of the investigations is to establish a relationship between the geometrical parameters of the board with its resonance frequency and its quality factor

Numerical results for selected structures (2)

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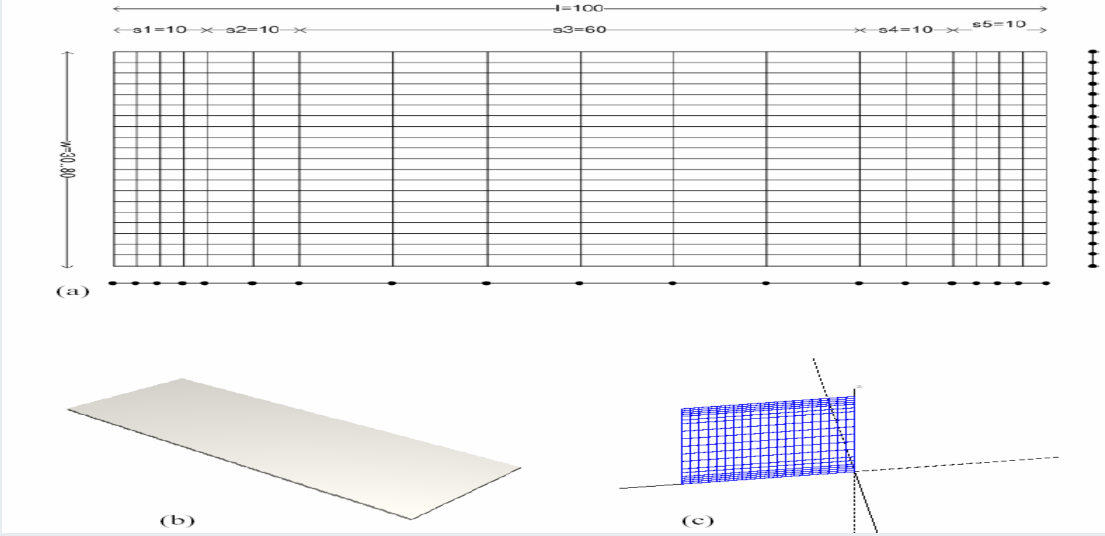
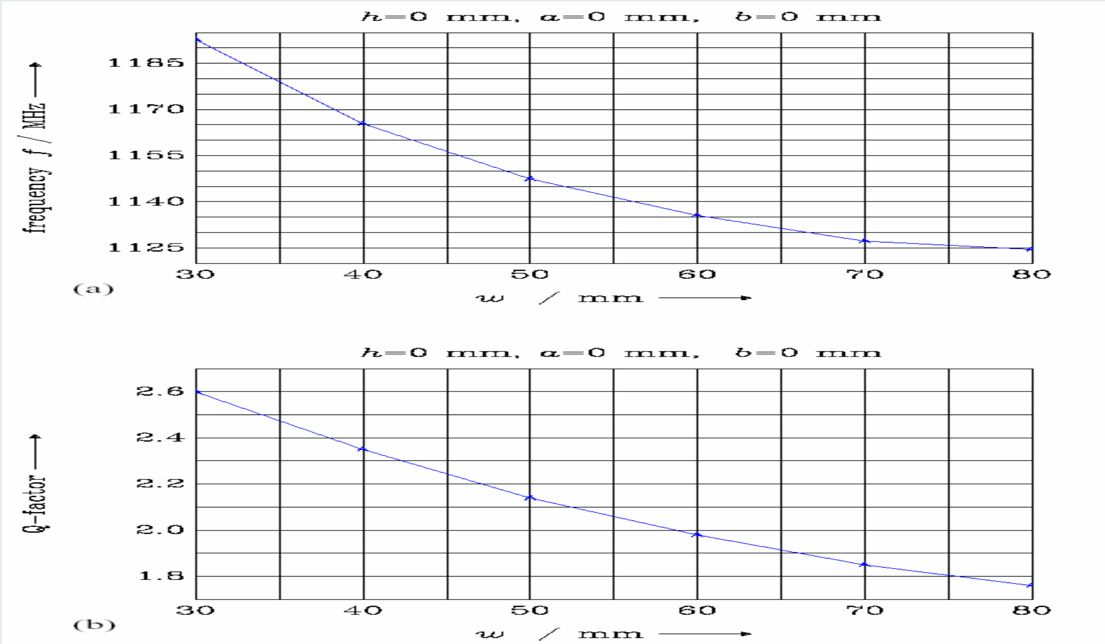
Structure A

- Structure A is a simple board of length 100 mm and variable width from 30 to 80 mm, in steps of 10 mm.
- The frequency dependence of (a) resonance frequency and (b) quality factor can be seen on the right side.





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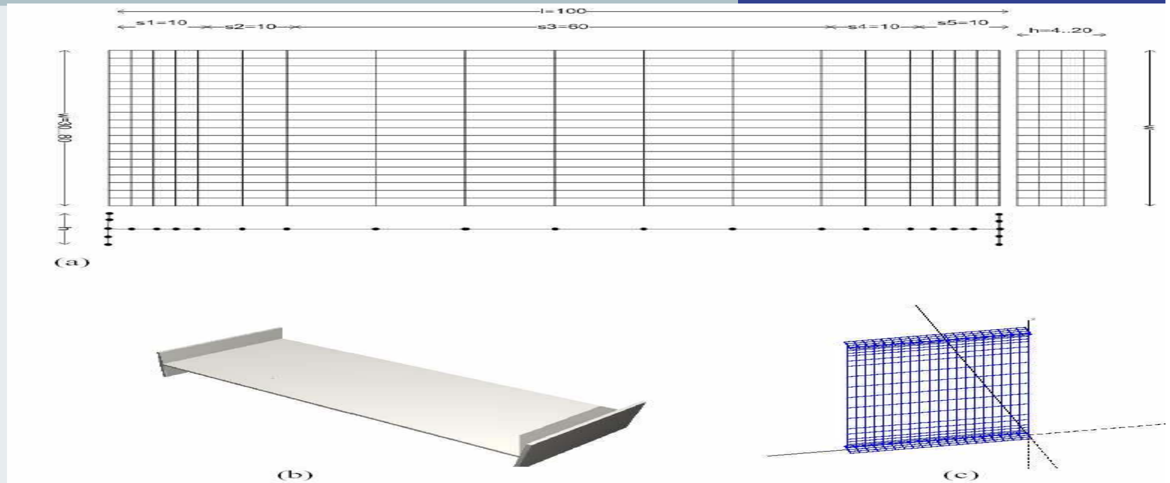
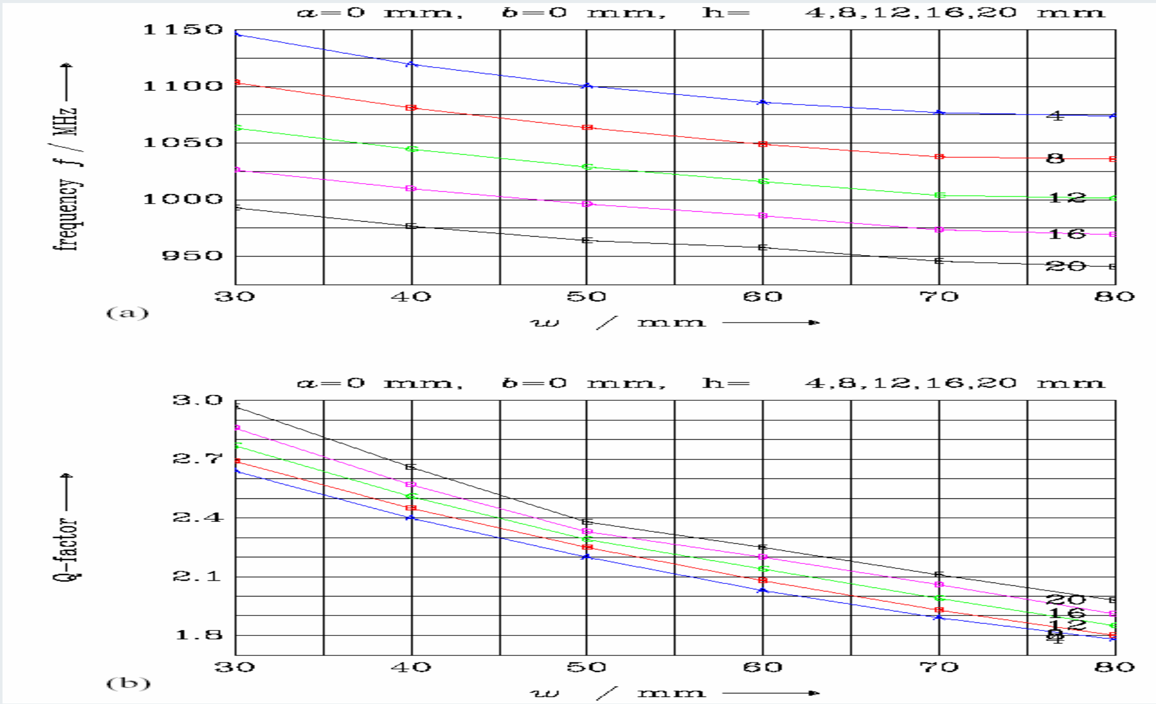
Numerical results for selected structures (3)

Structure B

- In order to extend the electrical length of the board, capacitive load are added to each end of the board
- The structure obtained is called structure B
- Discretization shema of structure B can be found on the right side
- The parameters of structure B are l, w and h
- The frequency dependence of (a) resonance frequency and (b) quality factor of stucture B can be seen on the right side.

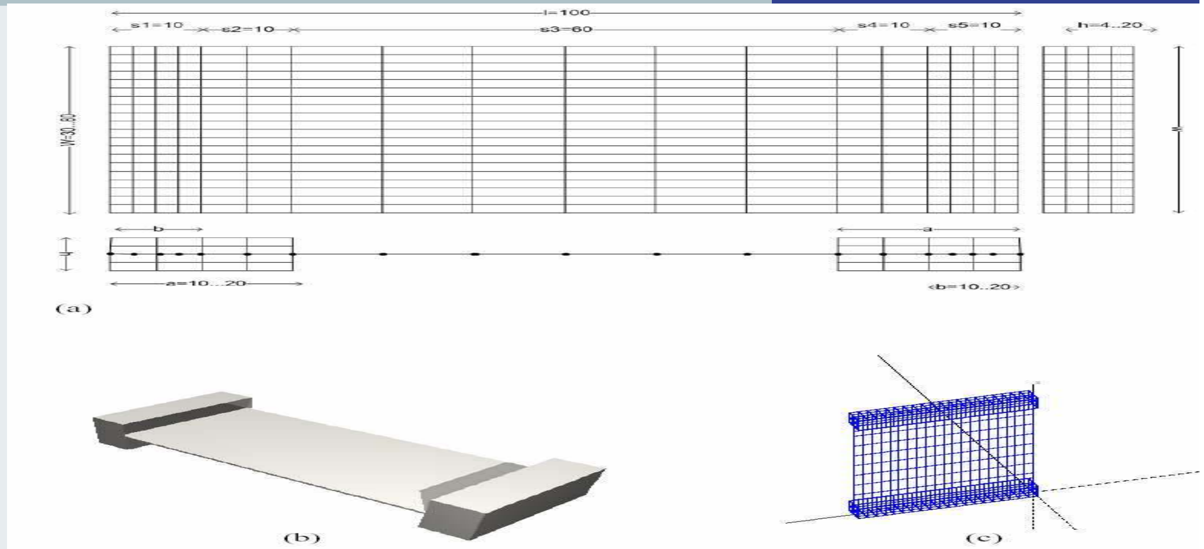


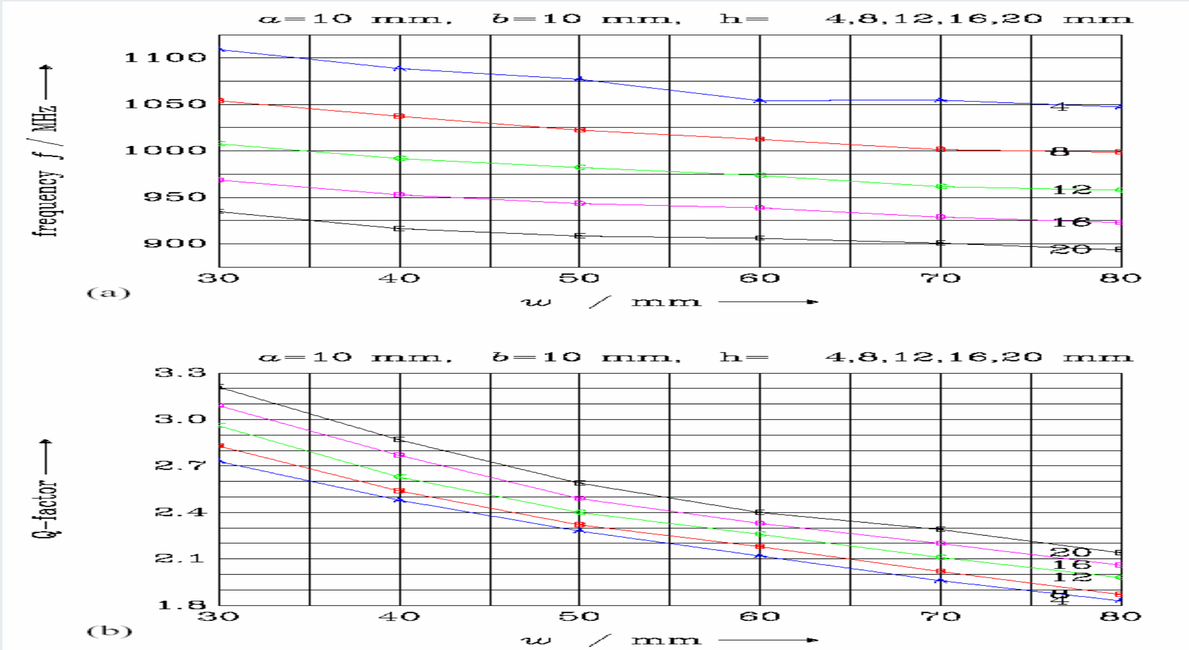


Numerical results for selected structures (4)

Structure E

- Structure E has six parameters: l, h, w, a, b, and h.
- Discretization shema of structure E can be found on the right side
- The frequency dependence of (a) resonance frequency and (b) quality factor of stucture E in cases a=10 mm, b=10 mm can be seen on the right side.





Numerical results for selected structures(4)

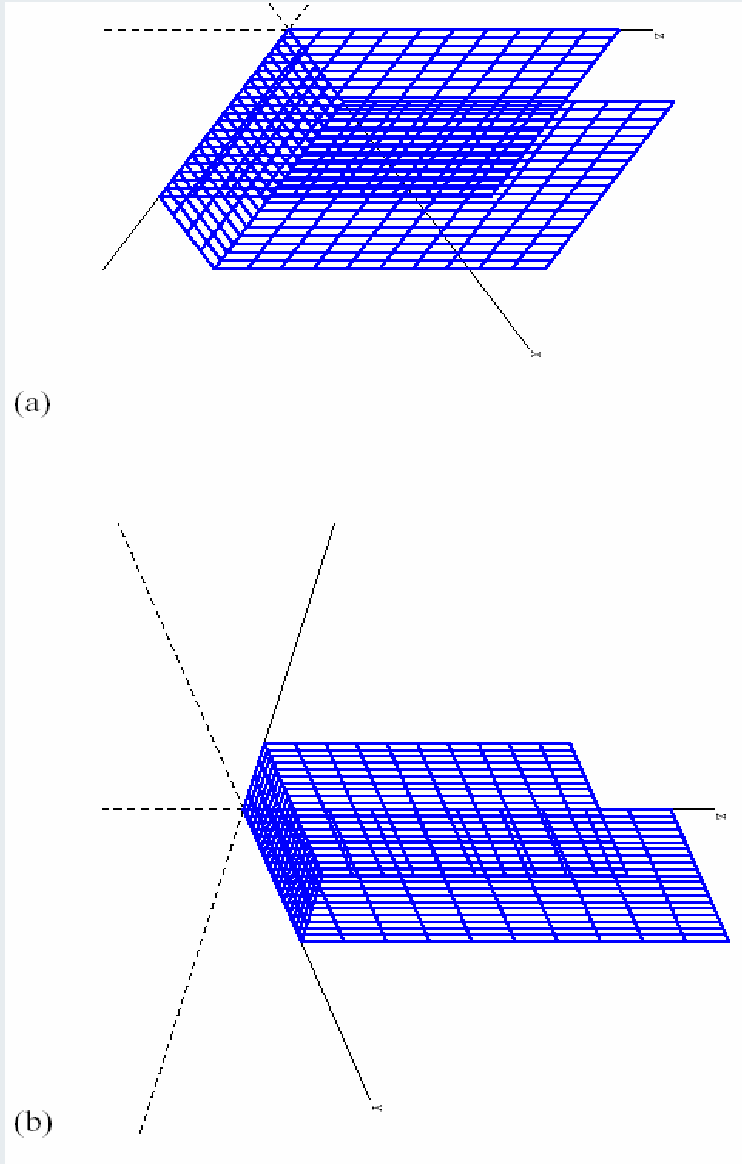
- Folder type phone
- Folder type phones are getting more and more popular.
- It is useful to observe how a folder type chassis radiates
- For suitable observations, one should consider the folder type phone at closed and open state.
- Only the closed state is considered here.

Numerical results for selected structures (5)

- The structure on the right presents a strongly simplified wire grid model of a closed folder type phone with width w=35 mm, thickness h=15 mm and (a) equal lengths of the low and upper part of 60 mm, (b) different lengths of the low part of L1=70 mm and upper part of L2=50 mm

- Considering a z-polarized plane wave illumination and assuming as above that the resonance frequency of the chassis is given when $|e_z F_0|$ is maximum, the two folder type chassis are excited with different frequencies from 500 to 5000 MHz in steps of 20 MHz respectively.

- For each frequency, the corresponding $|e_z F_0|$ is computed



Numerical results for selected structures (6)

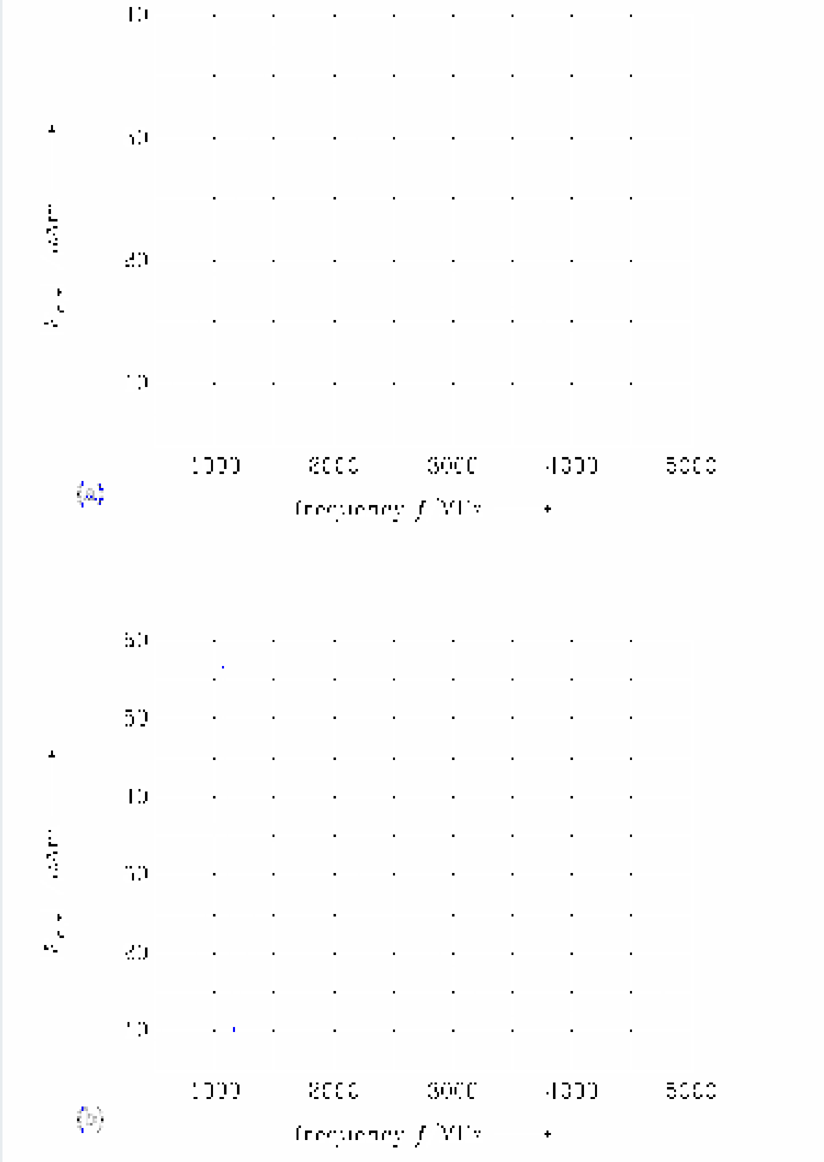
- As the results of the simulation, the curves on the right side were obtained

- When considering a folder type of equal lengths, only one maximum is found

- When considering a folder type with different lengths, two maximum are found although the total length of the chassis (L1+L2) is maintained constant to 120 mm as in the case of equal lengths.

- From the above obsevations, one can say that it is possible to get a dual band chassis from a folder type chassis

- The ony thing to do is to consider different lengths of lower and upper part



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Numerical results for selected structures (7)

- Normally, the folder type phone is more complicated as assumed.
- The first moment of the radiation vector is not sufficient to define its characteristics.
- The second moment should also be taken into account.

Conclusion

- In this work, it has been shown that the resonance frequency and the quality factor of the chassis of a mobile phone can be strongly influenced using suitable design details
- Chassis resonances were found using a generic exciter with frequency independent behaviour
- The first order resonance of different chassis models has been studied in details
- At the end, A simplified closed folder type has been shown.
- Here it has been noticed that the first moment of the radiation vector is not sufficient.
- The second moment should also be considered
- This can be done in future works.

Thank you for your attention