Inverse Convolution Method for Periodic Media under Deterministic and Stochastic Condition

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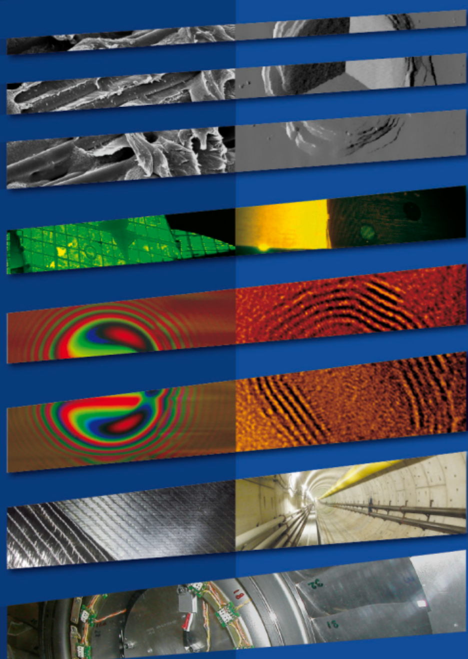

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Profile

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Research

Direction: Periodic media, Wave propagating, Vibration control

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I. The background of INCOME
II. Inverse methods for wavenumber extraction
III. The theory of 1D deterministic INCOME
IV. Application cases
V. The prospection of 1D stochastic INCOME

The background of INCOME

Background

- Periodic structure

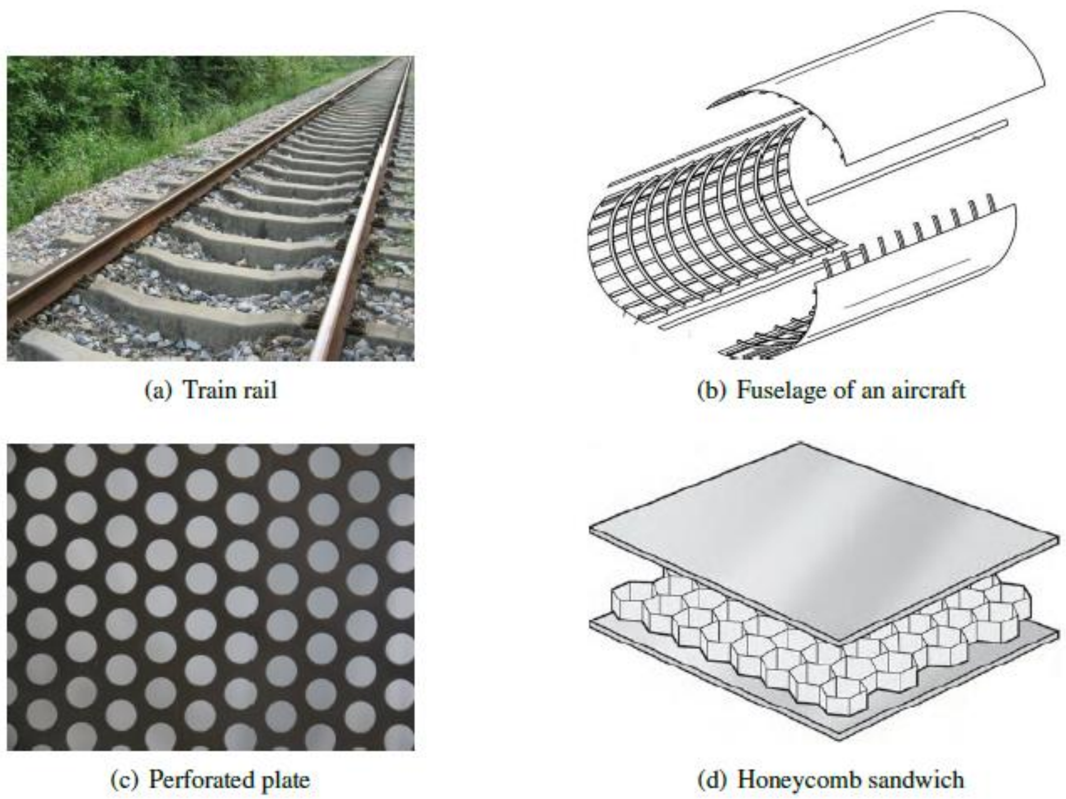
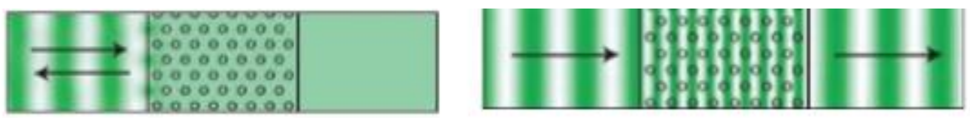


Fig.1 Periodic structure

- Characteristic: Attenuation band



(a) Band gap (b) Pass band

Fig.2 Schematic diagram of the band structure

- K-space---------Dynamical behavior

✓ Structural optimization in aerospace and civil engineering: vibration isolation, unable filters.

✓ The arrival estimation for sonar and radar, protection of electrical power lines and so on.

- Uncertainties---------Practical meaning

Achieve more realistic k-space characteristics' identification

- Block diagram of Inverse methods

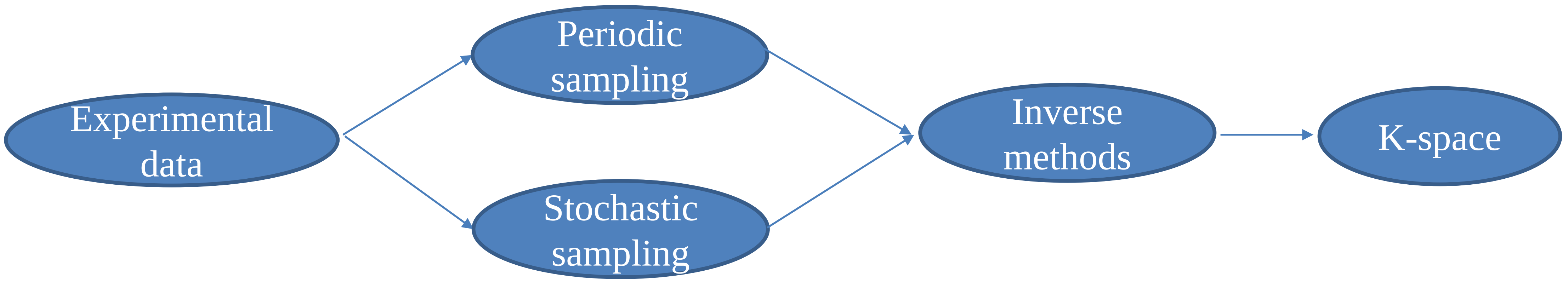
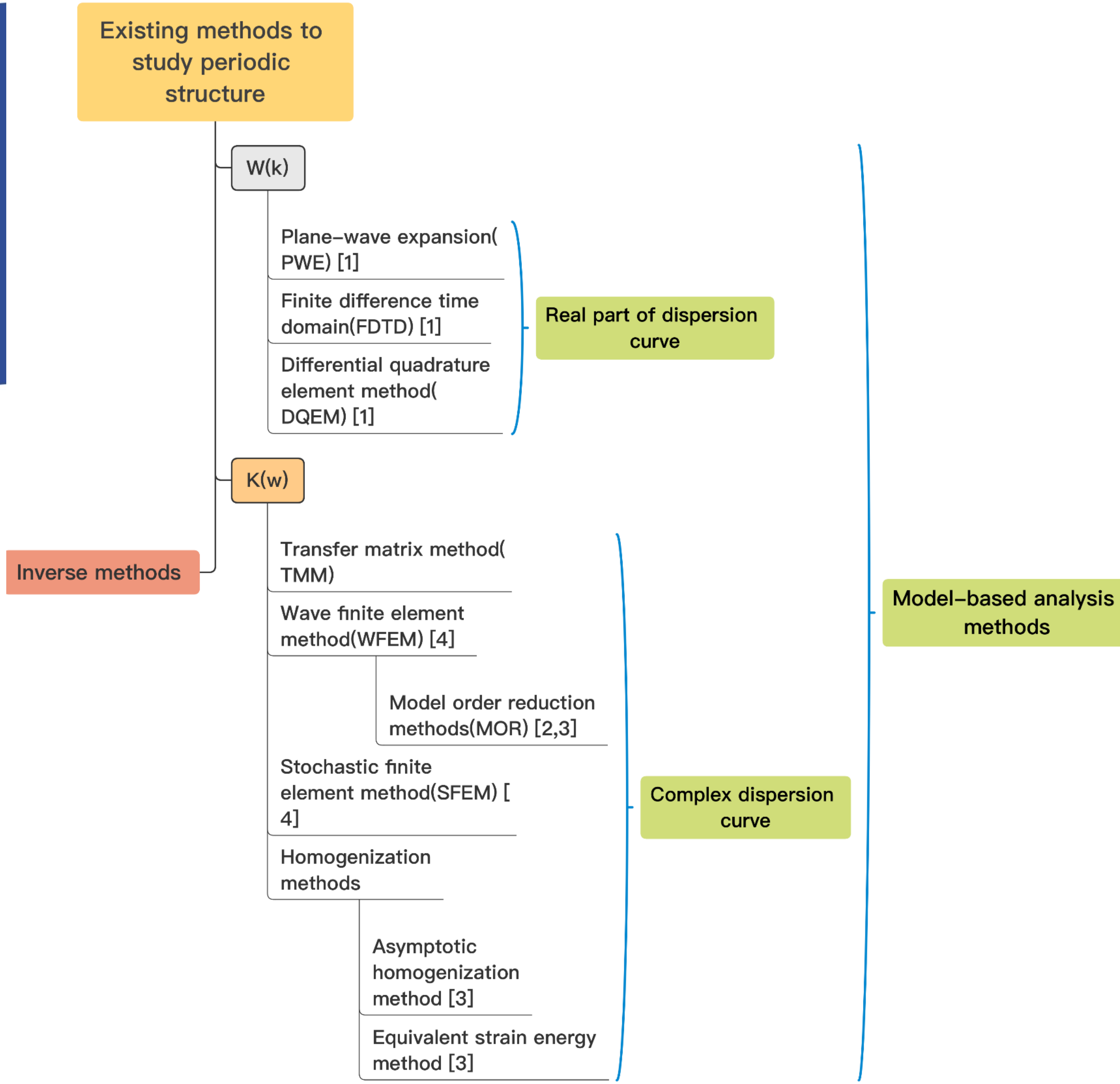


Fig.3 Block diagram of inverse methods

Inverse methods for wavenumber extraction

• Existing methods to study periodic structure



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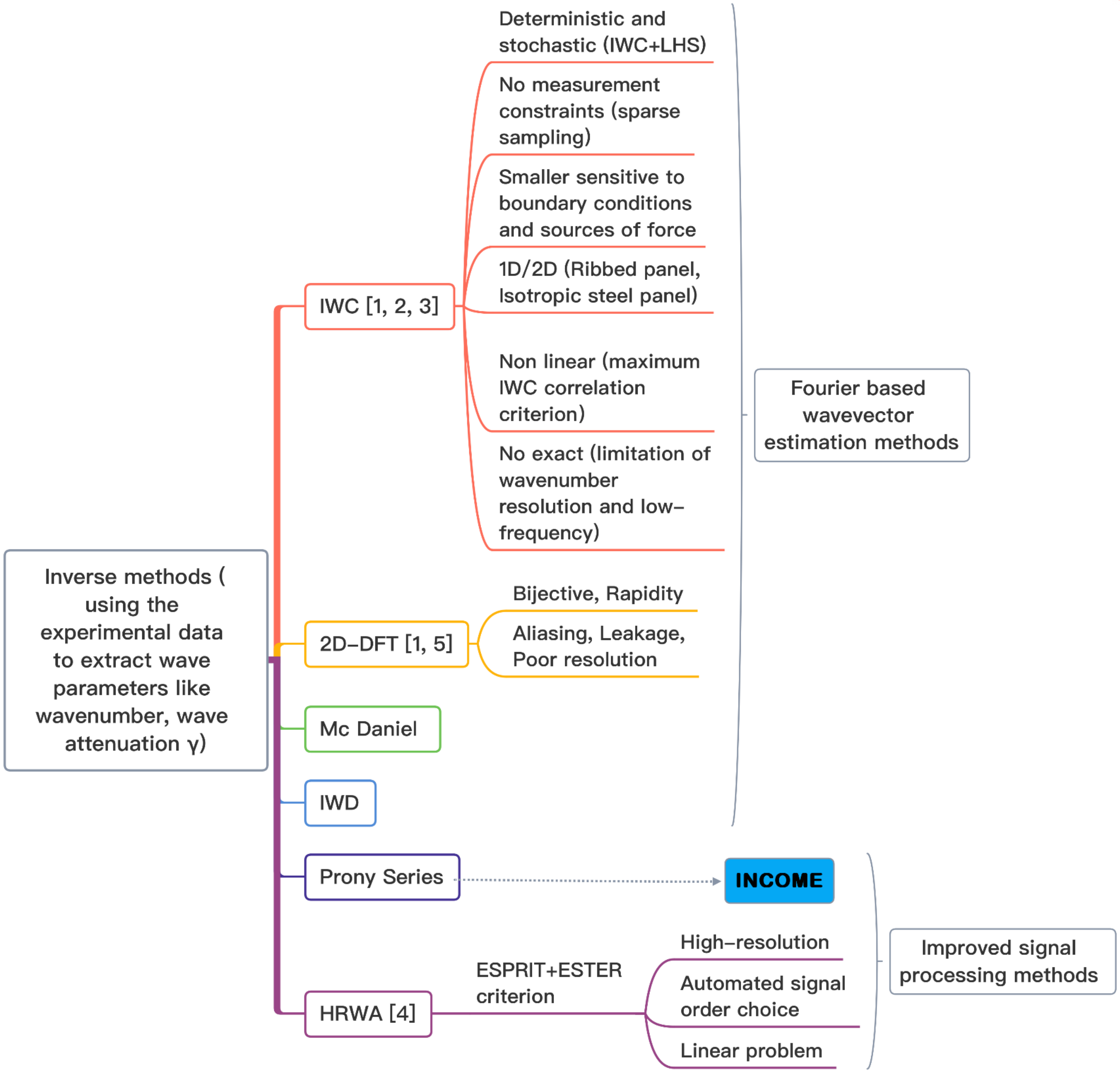
- K-space analysis methods



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The theory of 1D deterministic INCOME

- Deterministic

INCOME: Modeling + Wavenumber identification

- Assumed modeling: $U_n = \sum_{m=1}^{n_w} b_m exp(jk_m x_n) + e = \sum_{m=1}^{n_w} b_m \lambda_m{}^n$ +e $e = 0$ (1)

Bloch principle: $\lambda_m = exp(jk_m \Delta x)$ $x_n = n\Delta x$ (2)

Corresponding characteristic polynomial:

$$\psi(\lambda) = \prod_{m=1}^{n_w}(\lambda - \lambda_m) = \sum_{m=0}^{n_w} a_m \lambda^{n_w - m},\ a_0 = 1 \quad (3)$$

- Recursive difference equation : $U_n - \sum_{m=1}^{n_w} a_m U_{n-m} = 0 \quad n_w \leq n \leq N$ (4)

- Convolutional matrix formula: $(U_j) * (a_i) = 0\ (U_j)_{j\in[0,N]},\ (a_i)_{i\in[0,n_w]},\ a_0 = 1$ (5)

$$\mathrm{UA} = 0 \qquad \mathrm{U} = \begin{bmatrix} U_{n_w} & U_{n_w-1} & \cdots & U_0 \\ U_{n_w+1} & U_{n_w} & \cdots & U_1 \\ \vdots & \vdots & \cdots & \vdots \\ U_N & U_{N-1} & \cdots & U_{n_w} \end{bmatrix} \qquad \mathrm{A} = \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_{n_w} \end{bmatrix} \quad (6)$$

- Least square method: $U^* U x = 0$ (7)

- Bloch principle: $k_m = \frac{j ln \lambda_m}{\Delta x}$ (8)

Application cases

- A longitudinal propagating wave case

propagating positive wave

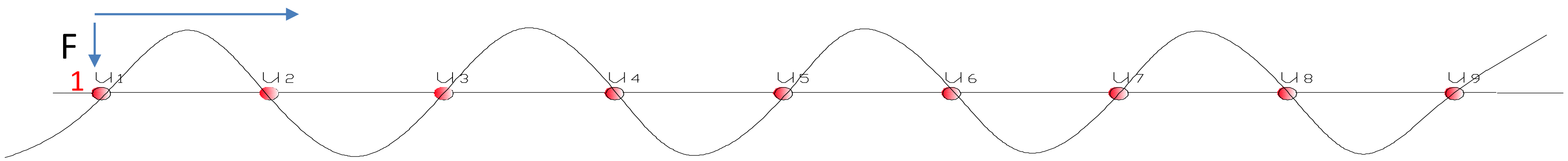

Fig.4 Longitudinal motion generated by a harmonic point force acting on a finite bar.

- Non-dimensional dispersion relation

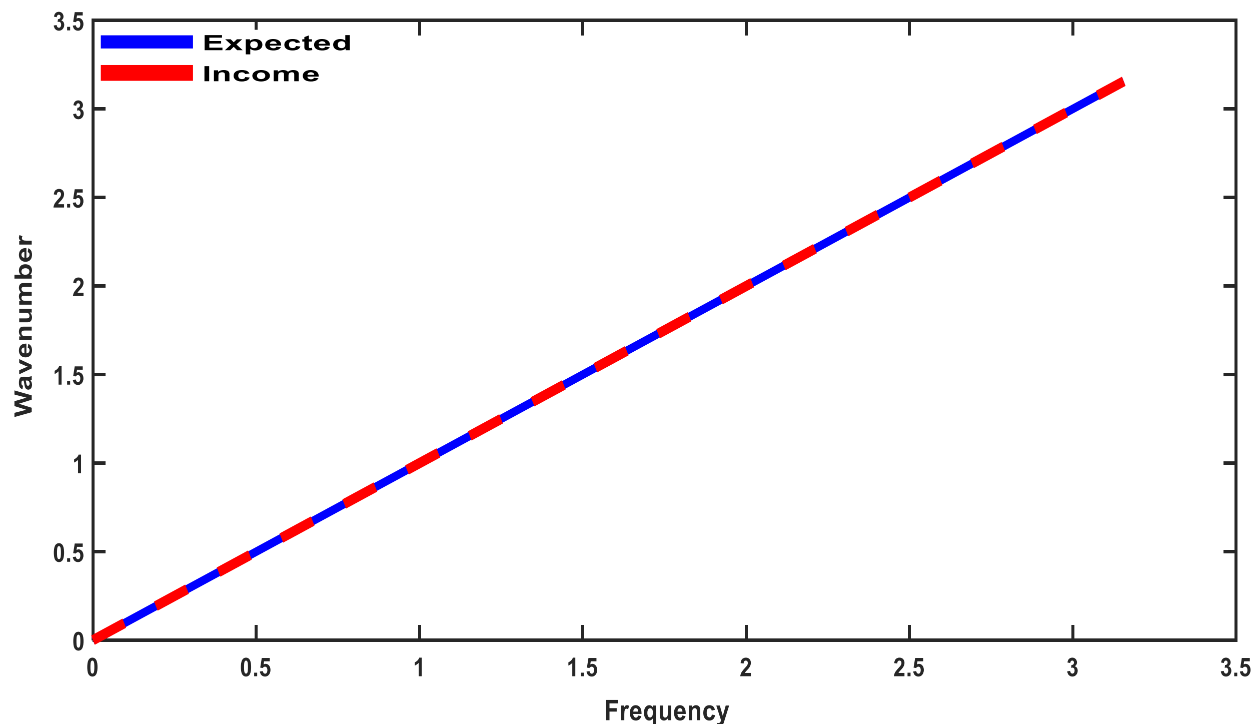

Fig.5 The real part of dispersion curve

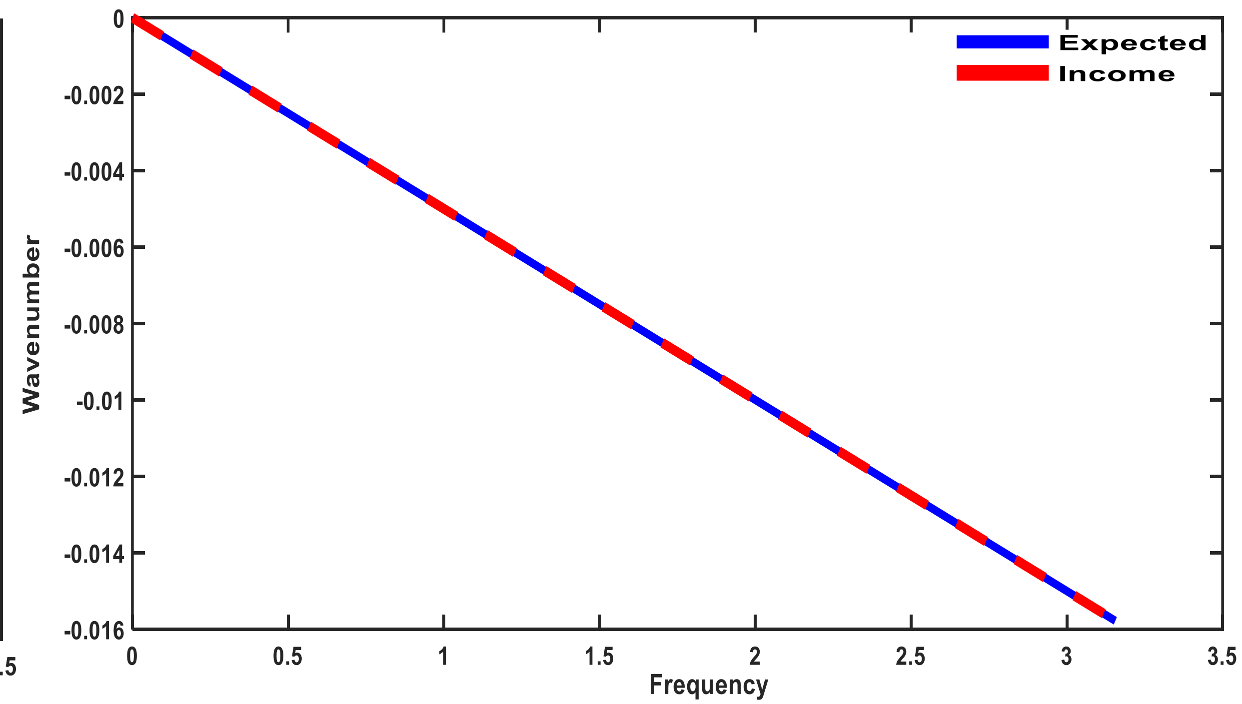

Fig.6 The imaginary part of dispersion curve

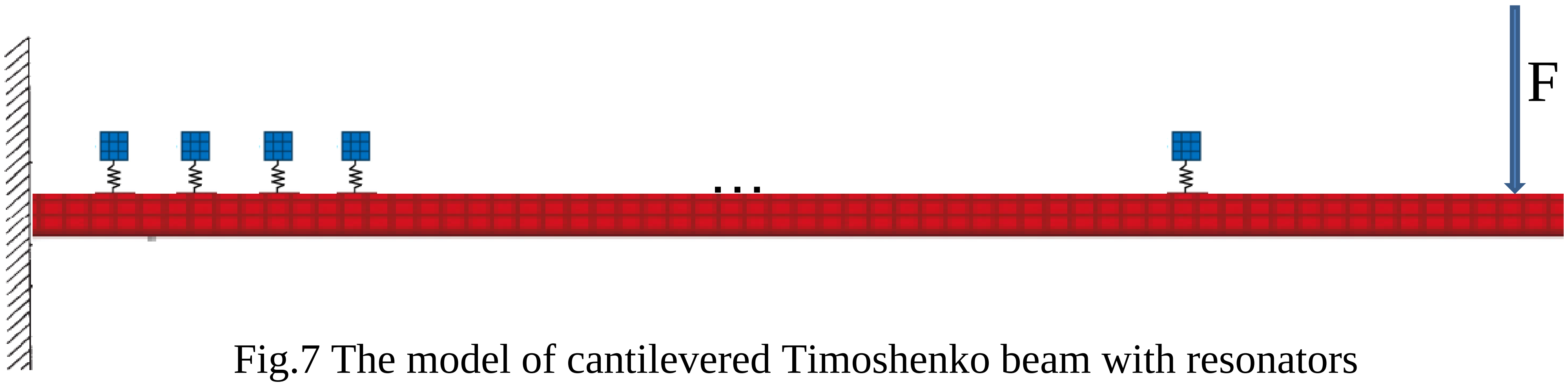

Fig.7 The model of cantilevered Timoshenko beam with resonators

- Resonators

  Natural frequency of resonators: 500 Hz

  Damping of resonators: 0.05

- Harmonic excitation

  $F = 10\sin(wt)$

WFEM: Expected dispersion curve

comparison

FEM: Displacement curve

INCOME: INCOME dispersion curve

- Frequency dispersion curve

Frequency=500Hz (the natural frequency of local resonator)

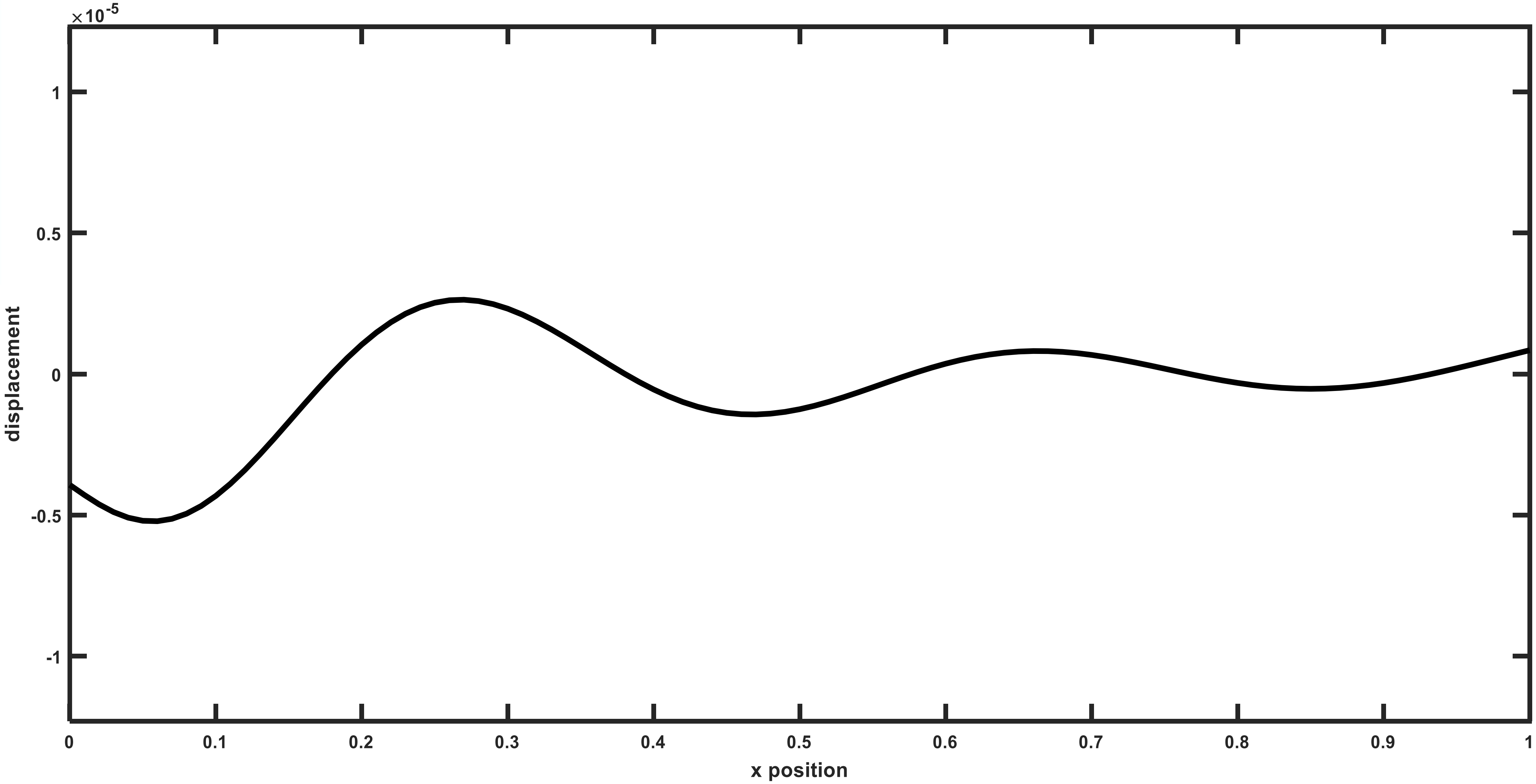

Fig.8 The frequency response curve

- The local resonator resonates with the main beam, causing the energy to decay exponentially, so that the wave cannot propagate, a band gap is generated and the displacement tends to zero with distance

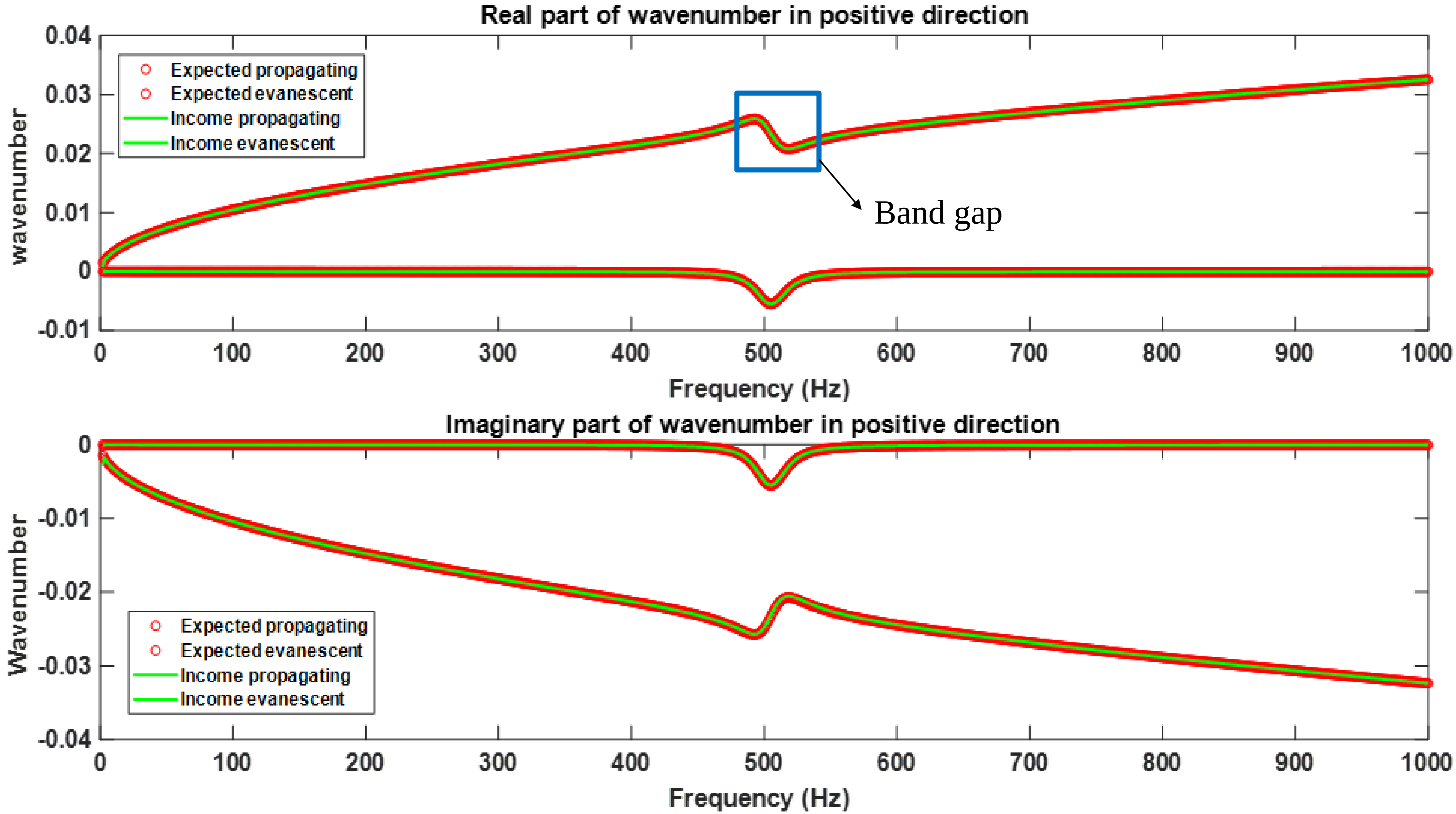

Fig.9 The complex dispersion curve of positive propagating wave

- The first band gap: 480Hz---520Hz

The prospection of 1D stochastic INCOME

- Assumed modeling $U_n = \sum_{m=1}^{n_w} b_m exp(jk_m x_n) + e$ $e \neq 0$

Uncertainty factors
- Noise: white Gaussian noise
- Non-periodicity measurements

- Wavenumber identification

✓ A sample-based uncertainty propagating method

✓ An automated estimation of signal order n_w

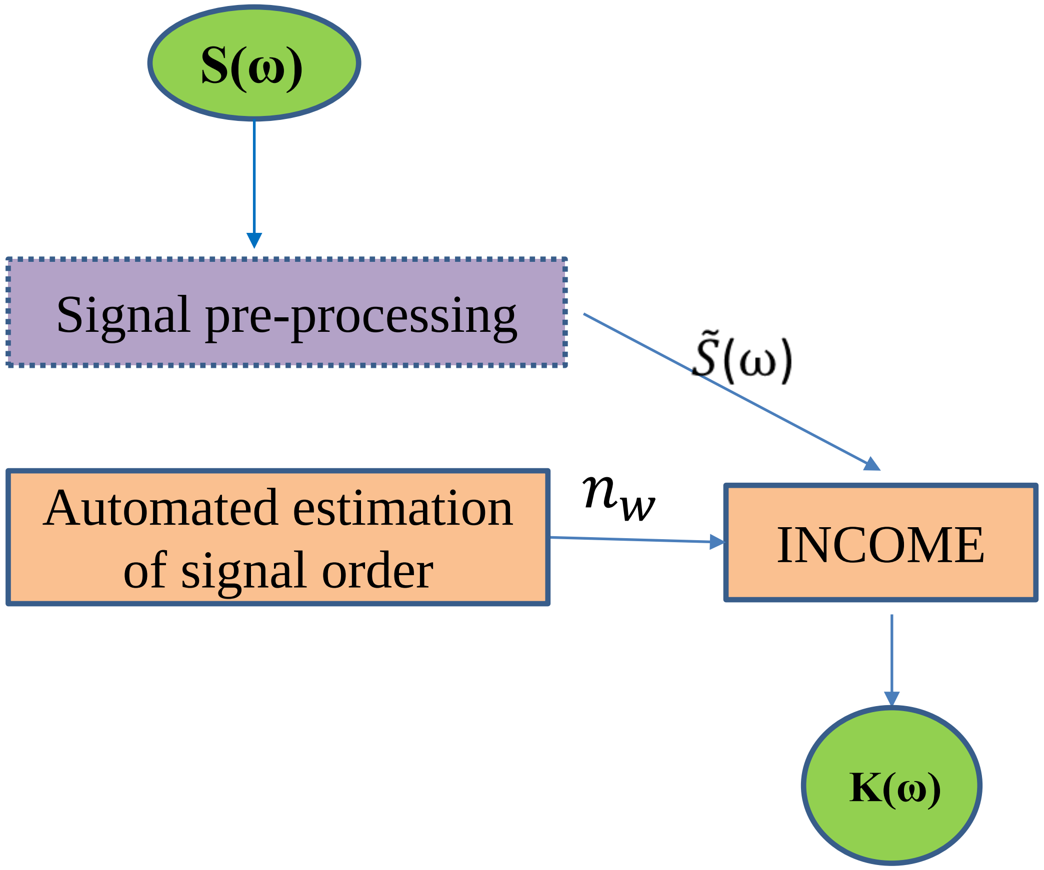

Fig.10 Block diagram of INCOME

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Thank you all for your time !