Application of Model-Based Parameter Estimation for fast frequency response calculations

Kakhaber Tavzarashvili, Christian Hafner, Ruediger Vahldieck

Laboratory for Electromagnetic Fields and Microwave Electronics,
Swiss Federal Institute of Technology,
ETH-Zentrum, Gloriastrasse 35, CH-8092 Zürich, Switzerland

e-mail: k.tavzarashvili@ifh.ee.ethz.ch
Outline

- Introduction
- Model-Based Parameter Estimation (MBPE)
- Applications of adaptive MBPE for the computation of
  - Dielectric waveguide propagation modes
  - Bend structures
  - Channel Plasmon Polaritons (CPP) propagation modes
- Conclusion
Model-Based Parameter Estimation (MBPE)

In the frequency domain, the response of a linear system may be optimally represented by a Cauchy’s method:

\[
F(s) = \frac{N(s)}{D(s)} + \text{Error}(s) = \sum_{i=0}^{n} N_i s^i + \text{Error}(s)
\]

\[
F(s_k) \sum_{i=0}^{d} D_i s_k^i - \sum_{i=0}^{n} N_i s_k^i = \text{Error}(s_k) \sum_{i=0}^{d} D_i s_k^i = E_k,
\]

\[
k = 1, \ldots, m
\]

\[
D_d = 1
\]

\[
F(s_k) \sum_{i=0}^{d} D_i s_k^i - \sum_{i=0}^{n} N_i s_k^i = -F(s_k) s_k^d + E_k = R_k + E_k,
\]

\[
k = 1, \ldots, m
\]

\[
m = m_0 = n + d + 1 \quad \text{we get square matrix system}
\]

\[
m > m_0 = n + d + 1 \quad \text{we get overdetermined system of equations}
\]

\[
m/m_0 \quad \text{overdetermination factor}
\]

The adaptive MBPE procedure

Start

Define maximum order
Overdetermination factor and desired interval of changing parameter

Construct data model; Solve system of linear equations for finding unknown coefficients $N_i$ and $D_i$; and estimate fitting error

Fitting error $< \varepsilon$ and $S \in [0,1]$

Yes

Find frequency point for next calculation and carry out calculation for defined frequency point.

No

Increase order or divide domain into sub domains

End

Procedure started from 5 uniformly distributed points and was finished after 16 iteration.
Application of MBPE to problem of coupled metallic nanoparticles

SCS is evaluated in 68 sample points marked by circles.

The system contains two circular cylinders made of silver with a radius of 25nm and a surface-surface separation. The Drude model was used for the frequency dependence of the permittivity of silver:

\[
\varepsilon(\nu) = 1 + \frac{i\tau\omega_p^2}{2\pi\nu(1 - i2\pi\nu)}
\]

Frequency dependence of the permittivity of silver (Drude model). In each MBPE domain a Cauchy approximation of order 10 was used.

Near-Filed around coupled circular nanoparticles
Dispersion curves for the various propagation modes of the circular dielectric waveguide. The speed-up factor from the adaptive MBPE compared to MAS or MMP brute-force is more than 25.
The calculation started with 6 frequency points. Finally, only 25 frequency points were computed and the remaining points were interpolated by MBPE. The speed-up factor provided by the MBPE is more than 10.
Channel Plasmon Polaritons (CPPs)

Dispersion behavior of various modes for the V-shaped groove waveguide carved in gold. The speed-up factor from the adaptive MBPE compared to MAS or MMP brute-force is more than 25.
Conclusion

- The adaptive MBPE may be added to any frequency domain field solver to speed up the computation. For this work the adaptive MBPE was combined with two semi-analytic field solvers, the MAS and MMP.

- MBPE may be used also when dispersive materials are present.

- MBPE was applied for speeding up the calculation of waveguides, metallic and metallo-dielectric PhCs, as well as Channel Plasmon-Polariton structures.

- In many cases the speed-up factor is of order 25.
Thank you for attention