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Editorial

Application of Computational Electromagnetics Techniques and Artificial Intelligence in the Engineering

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Since the establishment of Maxwell's equations in the 19th century, computational electromagnetics has undergone a century of stable development [1]. Numerical algorithms such as the finite difference method, the finite element method, the moment method, and the high-frequency approximation method have been developed, serving as important cornerstones in the field of modern electronics and information [2,3].

However, traditional computational electromagnetic algorithms, when faced with device optimization design scenarios that require a large number of repeated calculations, cannot effectively utilize historical data to mine the underlying physical laws; therefore, they cannot achieve faster iteration [4]. At the same time, traditional algorithms generate a large number of intermediate calculation results and cached data when computing large-scale simulation tasks, resulting in the wastage of computing resources [5].

Artificial intelligence algorithms, on the other hand, can automatically extract non-linear mapping relationships from electromagnetic simulation parameters to the required electromagnetic response through learning and training. This approach fully utilizes historical data information to improve the simulation efficiency, advancing intelligent electromagnetic computing [6].

Moreover, AI can enhance the efficiency and accuracy of reverse optimization tasks by introducing prior information on geometric features or other electromagnetic characteristics of optimization targets. This has achieved many representative results in applications such as antenna structure optimization, holographic imaging design, and inverse scattering imaging [7].

In recent years, a variety of optimization algorithms, such as the particle swarm optimization (PSO), the ant colony optimization (ACO), and differential evolution (DE), have received widespread attention. PSO, ACO, DE, and population-based incremental learning (PBIL) have gained recognition in filter design. A novel method merging MOEA/D and a 1D-CAE network structure is proposed to design microwave filters (Contribution 1). The 1D-CAE network structure replaces the traditional full-wave simulation, which greatly reduces the design time of the filter.

The design of a hybrid location service strategy is introduced (Contribution 2), including forwarding strategy selection, switching design, and forwarding strategy design, as well as the data packet transmission process based on a reactive routing protocol. At the same time, the network problems of small unmanned aerial vehicle systems (UAS), especially the routing problem of flight self-organizing networks (FANETs), are summarized, and the research status and future development directions of related routing strategies are discussed.

An improved combination method is presented (Contribution 3), which combines the Method of Moments (MoM) and Consistent Diffraction Theory (UTD) to calculate the radiation characteristics of antenna arrays installed on large electrical platforms. This method first sequentially feeds each array unit in a MoM processor and then inputs the results into the UTD process to calculate the perturbation pattern. When solving the current coefficient in MoM, the principle of linear superposition is used to achieve separate feeding

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for each array unit. This method can avoid the problem of unreliable UTD results when the equivalent phase center of the antenna is obscured and reduce the root mean square error from over 15 dB to about 1 dB in the given T-shaped example. Furthermore, this method does not require a significant amount of computing resources.

The effect of introducing a collector ring on the grounding loss resistance of a very low frequency (VLF) umbrella transmitting antenna grounding system is investigated (Contribution 4). By establishing a geometric deconstruction model of the collector ring, a VLF umbrella transmitting antenna model, an umbrella antenna ground network system model, and an average conductivity formula, the working principle of the collector ring is analyzed. The simulation of the grounding loss resistance of collector ring structures with different layers and degrees of damage using Feko software is described. The simulation results show that, in the case of intact and undamaged ground grid system, increasing the number of collector rings has a relatively weak impact on the ground loss resistance. However, when the local network conductor breaks, the collector ring structure can effectively reduce the grounding loss resistance.

An improved diode SPICE model based on measurement and nonlinear fitting stochastic optimization algorithm is proposed (Contribution 5). By analyzing the electromagnetic interference mechanism and characteristic parameters of the diodes in detail, the model accuracy is successfully improved. The experimental results show that the model can truly reflect the characteristics of electromagnetic interference, ensuring that the harmonic components and amplitudes are within three times the fundamental frequency and verifying the accuracy of the electromagnetic compatibility model.

For solving high computational costs in filter optimization problems, an adaptive online updated 1D convolutional autoencoder (AOU-1D-CAE) surrogate model is proposed (Contribution 6). This model can automatically collect, select, and use data as training samples, and as the number of samples increases, the model's learning ability gradually strengthens. The experimental results indicate that the AOU-1D-CAE improves the data collection efficiency and enhances the predictive performance. Combined with Particle Swarm Optimization (PSO), this surrogate model can assist PSO in finding the global optimal solution, avoid falling into local optima, and improve optimization efficiency. The effectiveness of the proposed surrogate model is verified using examples of two cavity filters.

The finite difference time domain method is adopted to comprehensively analyze the impact of front and rear door coupling on electronic devices, considering the coupling scheme of the voltage source injection and plane wave irradiation occurring simultaneously, and introducing an improved equivalent circuit model based on physical models (Contribution 7). Taking PIN limiters as an example, the authors analyze their performance impact and propose suggestions for protection.

A method to measure the shielding effectiveness of irregular cavities is proposed (Contribution 8). An electromagnetic topology model is established for the cavity, simulating its field distribution characteristics. Combined with testing methods for regular cavities, a comprehensive approach to characterize and test the shielding effectiveness of irregular cavities is presented, effectively verifying its accuracy.

A novel tuning fork-shaped tri-band planar antenna (NTTPA) is introduced for multiple wireless communication bands (Contribution 9). Its asymmetrical design generates three operating bands, covering LTE, WLAN, and WiMax frequencies. Fabricated on FR4 with a compact size, it offers a wide bandwidth and stable radiation pattern. Ideal for wireless systems, it is cost-effective and easy to process.

In another article, artificial neural networks are used to predict the initial design of multiband planar antennas (Contribution 10). Trained on normalized antennas analyzed through modal analysis, the networks quickly select suitable geometries for desired operating bands. This neural pre-design concept simplifies and accelerates antenna design, promising to refine and enhance future multiband antenna designs.

A balanced bandpass filter is proposed (Contribution 11), which utilizes two half wavelength stepped impedance resonators to achieve a differential mode passband, with improved frequency selectivity, high common mode suppression, and wide stopband characteristics. The filter adopts a balanced U-shaped microstrip slot line transition structure for feeding, reducing design complexity. The simulation and measurement results are consistent, verifying the effectiveness of the design.

The design of a balanced bandpass filter based on slot line short cut loaded resonators is presented (Contribution 12); it has a wide differential mode bandwidth, steep passband selectivity, and high common mode suppression characteristics. By adjusting the size and gap of the resonator, the passband performance can be flexibly controlled. It adopts a U-shaped microstrip line to the slot line transition structure to achieve broadband common mode suppression and simplify design. The experimental verification shows that the performance of the filter is good, and the simulation and measurement results are consistent.

Conflicts of Interest: The authors declare no conflict of interest.

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