Hybrid Real-Binary Particle Swarm Optimization (HPSO) for Dual-Band Handset Antenna Design

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The ever demanding challenges in improving the performance of wireless communication systems require an antenna to be optimized with more geometrical flexibilities. For instance, in the design of a multi-band patch antenna, an ideal optimizer should have the capability to select a proper antenna configuration, as well as fine-tune the antenna's geometry to obtain multiple resonances at desired frequencies. In conventional continuous optimizers, i.e, the real-number PSO (RPSO) and real-number genetic algorithm (RGA), the basic antenna configuration is fixed and a set of real-valued parameters are optimized to implement the geometry fine-tuning. The designer's *a priori* knowledge therefore becomes critical in suggesting an appropriate starting point of the optimization. On the other hand, with binary optimization techniques such as binary PSO (BPSO) and binary GA (BGA), the configuration or the material selection of the design is represented by a binary string to be explored by the optimizer. However, the computational cost is often expensive when extremely long binary strings are applied to represent some essentially real-valued parameters via a binary-to-real mapping.

In this paper, a novel hybrid real-binary PSO (HPSO) algorithm is proposed, with candidate antenna designs represented by hybridized vectors to accomplish both geometry fine-tuning and configuration exploration simultaneously. Since the volocity/position updating equations in PSO are in the form of vector summations, the relatively independent real part and binary part in a hybridized vector enable the HPSO algorithm to be simply formulated by dealing with them by the velocity/position updating schemes of RPSO and BPSO, respectively. Functional testing of the algorithm demonstrates that HPSO is more computationally efficient than conventional binary optimizers by significantly reducing the dimensionality of solution space.

As an example, HPSO is applied to design a handset antenna operating at 1.8GHz and 2.4GHz for PCS and WLAN applications. The design space of 2cm×3cm and the feeding point are fixed on an 31-mil-thick RT/Duroid 5880 substrate (ϵ_r = 2.2) to resemble practical design limitations due to circuitry layouts. Using three real variables to represent the impedance transformer and an 120-bit long binary string for the radiating part, the configuration of optimal design is automatically explored to be a printed monopole loaded by dual branches. The measurement result of prototyped antenna shows S_{11} values of -18dB and -13dB at desired operating frequencies, along with 40% and 8% S_{11}<-10dB bandwidths at 1.8GHz and 2.4GHz, respectively. At both operating frequencies, omnidirectional patterns are observed in azimuth, and directional, monopole-like patterns elevation result into measured gains of 2.0dBi at 1.8GHz and 2.5dBi at 2.4GHz.