ORIGINAL ARTICLES

Wideband Patch Antenna Design Using Selective Particle Swarm Optimization

Mohd. Moniruzzaman, Md. Rafiqul Islam, Kamaruzzaman Sopian and Saleem H. Zaidi

Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.
Department of Electrical and Computer Engineering, Faculty of Engineering, International Islamic University Malaysia, 53100 Gombak, Selangor, Malaysia.

ABSTRACT

This paper presents an optimization technique for wideband patch antennas using selective particle swarm optimization (SPSO). SPSO is an improved variant of particle swarm optimization (PSO). Here, a special part of solution space is selected for PSO process. An application of this algorithm is developed for wideband patch antenna optimization. A stripes based antenna is designed by utilizing this algorithm. The performance of the antenna is observed by industry standard electromagnetic simulation software. The antenna shows 41.8 % bandwidth at -10 dB return loss, which is suitable for wideband applications.

Key words: Wideband patch antenna, particle swarm optimization, selective particle swarm optimization.

Introduction

Patch antennas have wide applications in portable communications devices because of their low profile and cost. However, the bandwidth of conventional microstrip patch antennas is much narrow. Several methods are available for widening the bandwidth of these antennas. Some examples are utilization of multiple resonators, various feeding and impedance matching techniques, slot antenna geometry, low dielectric substrate etc (Afshinmanesh et al., 2008). Conventional trial-and-error techniques to optimize patch antennas require much human interaction. Suitable optimization techniques may be used to automate and speed up this process.

For developing an automated method of antenna optimization, several popular optimization techniques like particle swarm optimization (PSO) (Moniruzzaman et al., 2011) and genetic algorithms (GA) (Zhang et al., 2009) with many of their improved variants are reviewed. Finally, selective particle swarm optimization (SPSO) is utilized in this work to optimize wideband antennas. It is a modified version of PSO. Here, a special part of solution space is selected for PSO process. A stripes based patch antenna is optimized using SPSO. The optimized antenna shows 41.8 % bandwidth at -10 dB return loss. Ansoft HFSS and MATLAB are used as simulation and optimization tools.

Antenna Geometry:

Geometry of the stripes based patch antenna is presented in Figure 1. The patch consists of 10 horizontal stripes, each 2 mm width. The ground is 30 mm length and 10 mm width. Through the vertical line in the center, the antenna is divided in two mirrored copies. This provides a symmetrical radiating element. The lengths of the 15 stripes of the patch and ground are denoted by $x_1$ to $x_{15}$. These first 10 parameters are selected and optimized by the SPSO programs. The entire patch, consisting of 10 stripes, is connected to the wave port by a 10 mm x 2 mm vertical stripe. The antenna is printed on a double sided FR4 substrate of $\varepsilon_r = 4.4$ and $\tan \delta = 0.02$. The substrate is 30 mm x 30 mm and 1.6 mm thick.

Selective Particle Swarm Optimization (SPSO):

In particle swarm optimization (PSO), an organization of particles is presented as a possible solution (Robinson and Rahmat-Samii, 2004). Here, each particle $p$ is related with vectors $V_p$ and $X_p$. Initially $V_p$ and $X_p$ are assigned by random vectors.

$V_p$ = Velocity vector
$X_p$ = Position vector.
$D$ = Dimensions of the solution space.
$v_{pd}$ = Velocity of $p^n$ particle on $d^n$ dimension
$x_{pd}$ = Position of $p^n$ particle on $d^n$ dimension

Corresponding Author: Mohd. Moniruzzaman, Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.
E-mail: Mohd.Moniruzzaman@gmail.com
\[ V_p = \{ v_{p1}, v_{p2}, \ldots, v_{pd} \} \]
\[ X_p = \{ x_{p1}, x_{p2}, \ldots, x_{pd} \} \]
\[ c_1 \text{ and } c_2 = \text{Acceleration coefficients} \]
\[ w = \text{Inertia weight} \]
\[ \text{rand}_1 \text{ and } \text{rand}_2 = \text{Independently generated and uniformly distributed random numbers. Range: } [0, 1] \]
\[ p\text{Best}_p = \text{Best fitness position for } p^{th} \text{ particle} \]
\[ g\text{Best} = \text{Best fitness position in the search space.} \]

\[ v_{pd} = w v_{pd} + c_1 \text{rand}_1 (p\text{Best}_pd - x_{pd}) + c_2 \text{rand}_2 (g\text{Best}_d - x_{pd}) \quad (1) \]
\[ x_{pd} = x_{pd} + v_{pd} \quad (2) \]

Using Euclidean metric, the optimization stage identifier \( osi \) is calculated as follows:

\[ \begin{align*}
N &= \text{Total number of members in the population} \\
D &= \text{Total number of dimensions} \\
ad_p &= \text{Average distance of a particle } p \text{ from other particles} \\
ad_b &= ad_p \text{ of the best particle} \\
ad_{\text{min}} &= \text{Minimum of all values of } ad_p \\
ad_{\text{max}} &= \text{Minimum of all values of } ad_p \\
osi &= \text{Optimization stage identifier} \\
\end{align*} \]

\[ ad_p = \frac{1}{N-1} \sum_{q=1,q\neq p}^{N} \sqrt{\sum_{d=1}^{D} (x_{pd} - x_{qd})^2} \quad (3) \]
\[ osi = \frac{ad_b - ad_{\text{min}}}{ad_{\text{max}} - ad_{\text{min}}} \quad (4) \]

**Results:**

The SPSO program was developed and run in MATLAB with 10 particles and 20 iterations. At -10 dB return loss, the bandwidth started at 2.4 GHz and ended at 3.67 GHz. So the bandwidth (BW) and center frequency \( f_c \) becomes 1.27 GHz and 3.035 GHz respectively. The fractional band width (FBW) is obtained as follows:

\[ FBW = \frac{BW}{f_c} \times 100 \% \quad (5) \]

Utilizing the above equation, the obtained FBW was 41.85%. The designed antenna is presented in Figure 1. Corresponding return loss graph is presented in Figure-2.

**Conclusions:**

A novel wideband antenna with 41.85% FBW is designed using selective particle swarm optimization (SPSO). Here, a special part of solution space is selected for PSO process. Euclidean distance is utilized to identify the evolutionary states of particle swarm optimization. Industry standard electromagnetic solver Ansoft HFSS and MATLAB are used as simulation and optimization tools. The size of the designed antenna is 30 mm X 30 mm. So it can be integrated easily in portable and handheld devices. The antenna is designed using widely available FR4 substrate, which facilitates low cost development. We conclude that the combination of the stripes based geometry and the selective particle swarm optimization (SPSO) algorithm is a suitable tool for designing wideband patch antenna.

![Fig. 1: Patch antenna geometry.](image)
**Fig. 2:** Return loss graph of the antenna.

**References**


