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Bandwidth Enhancement of Balanced Folded Loop Antenna Design for Mobile Handsets Using Genetic Algorithms

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Abstract— In this paper, a simple folded loop antenna (FLA) for handsets with relatively wide-band impedance, designed and optimized using genetic algorithms (GA). The FLA dimensions were optimized and evaluated using GA in collaboration with NEC-2 source code. Configuration of optimal FLA with excellent VSWR covering entirely the required GSM1800 frequency bands was found within the maximum generation. A prototype antenna was tested to verify and validate the GA-optimized antenna structure. The measured data have shown good agreement with predicted ones. Moreover, the capabilities of GA are shown as an efficient optimisation tool for selecting globally optimal parameters to be used in simulations with an electromagnetic antenna design code, seeking convergence to designated specifications.

1. INTRODUCTION

Recently, balanced antennas have drawn greatly interest to mobile phone antenna researchers due to their stable performance when held by mobile phone users. In the previous work [1, 2], folded dipole and loop antennas have shown the promising characteristics of balanced antennas in terms of their current distributions on ground plane, radiation performance and Specific Absorption Rate (SAR). One dramatic drawback in their proposed antennas for use in mobile handsets is the lack to provide enough impedance bandwidth to fulfill the bandwidth requirements for the current wireless mobile communications (i.e., GSM1800/1900 or UMTS). However, a wideband operation was achieved at higher central frequency 2680 MHz [3].

GA is random search methods based on the principle of natural selection and evolution [4]. An approach of using GA in cooperation with an electromagnetic simulator has been introduced for antenna designs and has become increasingly popular recently [5]. In authors' previous work [6], an example of enhancing bandwidth for mobile antennas has been demonstrated. The benefit of applying GA is that they provide fast, accurate and reliable solutions for antenna structures.

In this paper, a simple FLA for handsets with relatively wideband impedance, was designed and optimized using GA. The geometry of proposed FLA was adopted from the Morishita's work [1] (see Fig. 1) and applied here for this study due to the simple structure for the mobile antenna applications. The parameters used to define the FLA, were optimized and evaluated using GA in collaboration with NEC-2 [7, 8]. Finally, GA optimal antenna structure was verified with hardware realization. The corresponding results were compared to the predicted ones and a good agreement in VSWR was observed.

2. GENETIC ALGORITHMS AND ANTENNA OPTIMIZATION USING GA

A FLA was optimized with GA using real-valued chromosomes. The intended antenna was designed for GSM1800 applications (1710–1860 MHz). Performance of the randomly generated antenna samples was computed using NEC-2 and its result was compared with desired fitness using the following cost function:

$$F = \sum_{n=1}^3 W_n \cdot (1/VSWR(f_n)) \quad (1)$$

where, W_n ($n = 1, 2, 3$) are the weight coefficients for the cost function and initially, they set a value of 1. Three pre-set specific frequencies 1710, 1785, and 1860 MHz were applied. GA was run to calculate and evaluate the for each erratically produced antenna structure, in order to ensure the optimal antenna operation to cover the required impedance bandwidth. The objective was to find the optimal solution that satisfies certain constraints including a specific antenna volume.

GA input parameters, their constraints and the optimal values for each specified parameter of the design geometry is presented in Table 1. Since there is no graphical abilities in NEC-2, GA generated antenna structures can be viewed using the NEC-Win Professional[®] simulator [9].

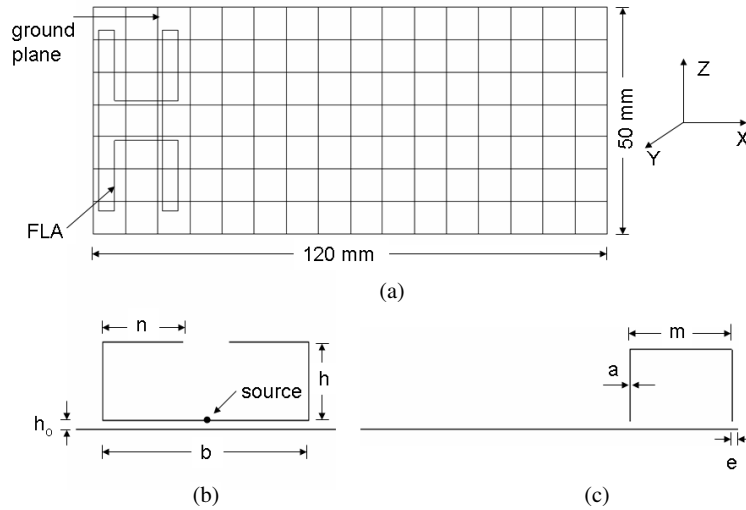


Figure 1: Antenna configuration studied, (a) balanced folded loop antenna with conducting plate, (b) front view of the antenna design, (c) side view of the antenna design.

3. SIMULATION AND MEASUREMENT RESULTS

Configuration of optimal FLA antennas, with excellent VSWR covering entirely the required GSM1800 frequencies bands, was found within the maximum generation; antenna parameters of the best designs are shown in Table 1. For comparison, an electromagnetic simulator based on the finite integration technique (FIT) was used to verify and validate the GA-optimized antenna structure [10]. It should be noted that thin striplines were employed in the EM modeling instead of thin wires that used in GA optimization, due to the fact for the purpose of practical implementation. Subsequently, a minor adjustment was applied to the GA-optimized antenna. The calculated antenna VSWR against frequency over the interested bands is shown in Fig. 2 and was compared to the one obtained from GA. As can be seen, an excellent agreement of antenna VSWR response was achieved. It is also notable that impedance bandwidth at $VSWR \leq 2$ was 7.5% at central frequency $f_0 = 1780$ MHz, compared to the bandwidth of 2.7% at $f_0 = 1860$ MHz with a small FLA and 5.4% with using a parasitic element added to the small FLA, as reported in work [1]. The bandwidth is comparatively broadened due to the effect of capacitive coupling between the antenna and ground plane in which it dominates the frequency band.

Table 1: Summary of GA input parameters, antenna variables and best solutions.

GA parameters	FLA for GSM1800		FLA for UMTS	
	Parameters (m)	Optimal (m)	Parameters (m)	Optimal (m)
Number of population size = 6	Wire radius (a) (0.0004-0.0008)	0.00074	Wire radius (a) (0.0004-0.0008)	0.000790
Number of parameters = 7	FLA length (b) (0.03-0.04)	0.03978	FLA length (b) (0.03-0.04)	0.03690
Probability of mutation = 0.02	FLA height (h) (0.003-0.012)	0.01173	FLA height (h) (0.003-0.012)	0.01179
Maximum generation = 500	FLA arm length (n) (0.002-0.015)	0.008785	FLA arm length (n) (0.002-0.015)	0.009881
Number of possibilities = 32768	Parallel wires distance (m) (0.005-0.015)	0.01489	Parallel wires distance (m) (0.005-0.015)	0.013599
Ground plane size (120 x 50 mm)	FLA distance to GP edge (e) (0.0-0.002)	0.0008643	FLA distance to GP edge (e) (0.0-0.002)	0.001137
	Distance between FLA and GP (h_0) (0.001-0.003)	0.001112	(h_0) (0.001-0.003)	0.001146

In addition, the same design principle and antenna geometry was applied to design and optimize antennas for 3G UMTS application. The comparative antenna VSWR (see Fig. 3) shows a good impedance matching over the intended band (11.3% at $f_0 = 2030$ MHz).

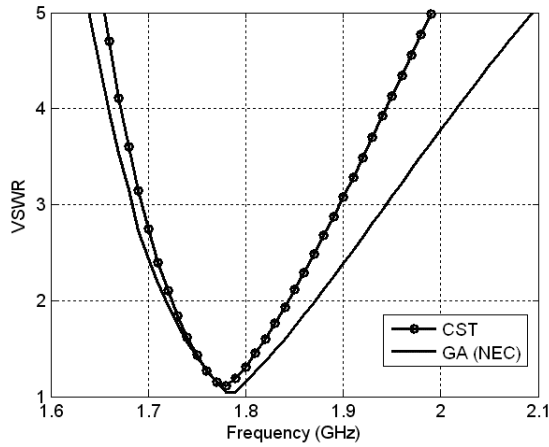


Figure 2: VSWR against frequency ($a = 2.070$, $b = 37.8802$, $h = 9.9991$, $h_0 = 1$, $n = 13.884$, $e = 0.9409$ and $m = 12.8052$, all dimensions in millimeters).

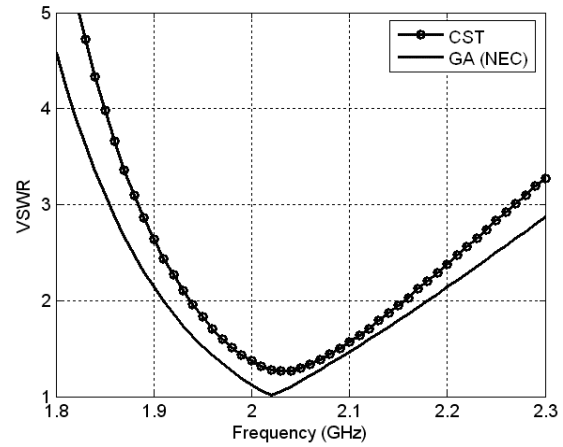


Figure 3: VSWR against frequency ($a = 1.95144$, $b = 37.0052$, $h = 9.9966$, $h_0 = 1$, $n = 11.1638$, $e = 1.8835$ and $m = 12.9884$, all dimensions in millimeters).

For the hardware realisation, copper sheet of thickness 0.15 mm and 0.5 mm was used for fabricating the balanced antenna and the ground plane (see Fig. 4). A balun, as a feeding network for the balanced antennas, is required to provide a balanced feed from an unbalanced source. In this study, a relatively wideband planar balun with sufficient frequency coverage and imbalance performance (covering 1.4–2.4 GHz frequencies bands with maximum 0.9 dB insertion loss in which the amplitude and phase imbalance are 0.1 dB and $\pm 2^\circ$, respectively) was employed to feed the prototype antenna.

Figure 5 presents the measured and simulated VSWR of the prototype antenna. As can be seen, taking into account the errors caused during antenna fabrication, a close agreement between the calculated and measured return loss was observed.

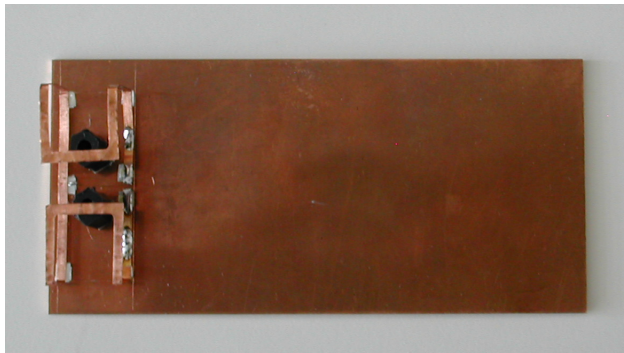


Figure 4: Photograph of fabricated prototype antenna.

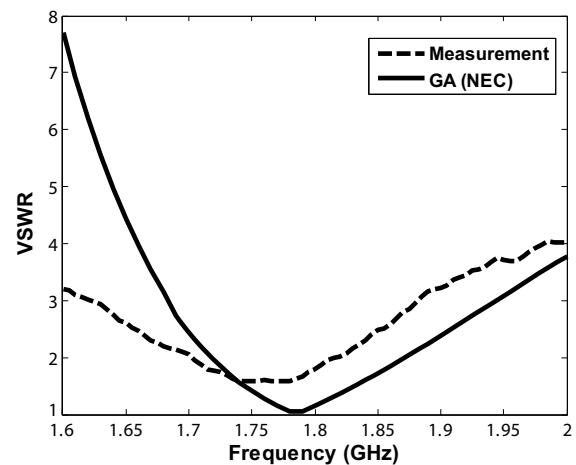


Figure 5: The simulated and Measured VSWR against operating frequency.

The radiation patterns in the z - x plane and z - y plane for the balanced folded antenna at 1780 MHz were calculated and plotted in Fig. 6, where the patterns of the proposed antenna are seen to be quite similar to each other at other frequencies inside the band. In addition, the z - x plane presents a nearly omni-directional radiation pattern in all intended frequency bands. For the GSM1800 band, the calculated peak gain was found to be 4 dBi.

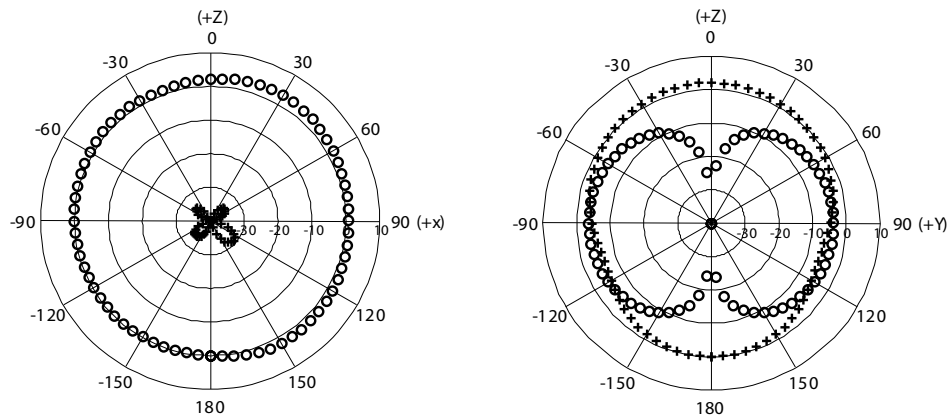


Figure 6: Radiation patterns for the proposed antenna at 1780 MHz in dBi at z-x plane (left) and z-y plane (right) ('+++ E_{θ} ' and 'ooo E_{φ} ').

4. CONCLUSIONS

A folded loop antenna with relatively wide bandwidth for mobile handsets, was designed and optimized using genetic algorithms. Performance of the GA-optimized antenna structure was validated through a hardware realization in which the simulated results show a good agreement with measured one. The GA has proven its advantage for quickly finding solutions for antenna designs as well as a robust technique to broaden the bandwidth in antenna design.

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