ACKNOWLEDGMENT

The authors would like to thank the National Chip Implementation Center for chip fabrication and the National Nano-Device Laboratory for measurement supports.

REFERENCES

1. C.H. Doan, S. Emami, A.M. Nikenjad, and R.W. Broadersoen, Millimeter-wave CMOS design, IEEE J Solid-State Circuits 40 (2005), 144–155.
2. B. Rong, J.N. Burghartz, L.K. Nanver, B. Rejaei, and M. van der Zwan, Surface-passivated high-resistivity silicon substrates for RFICs, IEEE Electron Device Lett 25 (2004), 176–178.
3. K.J. Herrick, T.A. Schwartz, and L.P.B. Katehi, Si-micromachined coplanar waveguides for use in high-frequency circuits, IEEE Trans Microwave Theory Tech 46 (1998), 762–768.
4. I.K. Itotia and R.F. Drayton, Porosity effects on coplanar waveguide porous silicon interconnects, IEEE MTT-S Digest, Seattle, WA (2002), 681–684.
5. M.T. Yang, T.J. Yeh, H.M. Hsu, P.C. Ho, Y.J. Wang, Y.T. Chia, and D.D.L. Tang, Characterization and modeling of high quality factor and broadband integrated inductor on Si-substrate, IEEE MTT-S Digest, Philadelphia, PA (2003), 1283–1286.
6. V. Milanovic, M. Gaitan, E.D. Bowen, and M.E. Zaghloul, Micromachined microwave transmission lines in CMOS technology, IEEE Trans Microwave Theory Tech 45 (1997), 630–635.
7. T. Wang, C.-H. Chen, Y.-S. Lin, and S.-S. Lu, A micromachined CMOS distributed amplifier by CMOS compatible ICP deep-trench technology, IEEE Electron Device Lett 27 (2006), 291–293.
8. Y. Eo and W.R. Eisenstadt, S-parameter-based IC interconnect transmission line characterization, IEEE Trans Compon Hybrids Manuf Technol 15 (1992), 483–490.
9. K. Nishikawa, K. Shintani, and S. Yamakawa, Characteristics of transmission lines fabricated by CMOS process with deep n-well implantation, IEEE Trans Microwave Theory Tech 54 (2006), 589–598.

QUADRIFILAR HELICAL ANTENNA DESIGN FOR SATELLITE-MOBILE HANDSETS USING GENETIC ALGORITHMS

D. Zhou,[1] R. A. Abd-Alhameed,[1] C. H See,[1] P. S. Excell,[2] Y. F. Hu,[1] K. Khalil,[1] and N. J. McEwan[1]

[1] Mobile and Satellite Communications Research Centre, Bradford University, Bradford, West Yorkshire, BD7 1DP, United Kingdom; Corresponding author: r.a.a.abd@bradford.ac.uk

[2] North East WALES Institute of Higher Education, Wrexham, LL11 2AW, United Kingdom

Received 11 February 2009

ABSTRACT: *A circularly polarized quadrifilar helical antenna, operated at 2.4 GHz and intended for applications in satellite mobile communications, is designed using genetic algorithms (GA). The antenna was firstly considered as a test on an infinite ground plane and then optimized further on small size handsets. The performance of the optimized antenna design was analyzed using commercial simulators in terms of impedance match, axial ratio, and gain. Results for the optimal antenna met the design objectives subject to certain parametric constraints. The design shows the capabilities of GA as an efficient optimization tool for selecting globally optimal parameters to be used in simulations with an electromagnetic antenna design code, seeking convergence to specific design specifications.* © 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 2668–2671, 2009; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.24694

Key words: *circular polarization; quadrifilar helical antennas (QHA); genetic algorithm (GA)*

1. INTRODUCTION

Genetic algorithms (GA) are random search methods based on the principle of natural selection and evolution [1]. An approach of using GA in conjunction with an electromagnetic simulator has been introduced for antenna designs and has become increasingly popular as presented in [2]. For example, GA was applied to design wire antennas [3, 4] and microstrip antennas [5, 6]. The benefit of applying GA is that they provide fast, accurate, and reliable solutions for antenna structures.

A quadrifilar helical antenna (QHA) is a very attractive candidate antenna for satellite mobile handsets because of the symmetry of their geometry, properties of balanced feeding, and their ability to provide circular polarization over a broad angular region [7].

Presented in this article are results of a study in which GA are applied to design and optimize QHAs for inclusion in a small size satellite mobile handset for circular polarization. The optimal solution of the antenna structure derived using GA was constructed and examined in detail against the simulation results.

2. GENETIC ALGORITHM

The GA driver, written in Fortran, was adopted in this work in conjunction with the industry-standard NEC2 Fortran source code, which was used to evaluate the randomly generated antenna samples [8, 9]. A QHA was proposed for optimization with GA. In this instance, real-valued GA chromosomes were used. Antenna parameters such as the VSWR and axial ratio (AR) are optimized at 2.44 GHz operating frequency. Each antenna sample was computed using NEC2 source code and its results were compared with desired fitness using the following cost function 'F':

$$F = W_1 \times (1/\mathrm{VSWR}) + W_2 \times A_1R_1 \qquad (1)$$

where

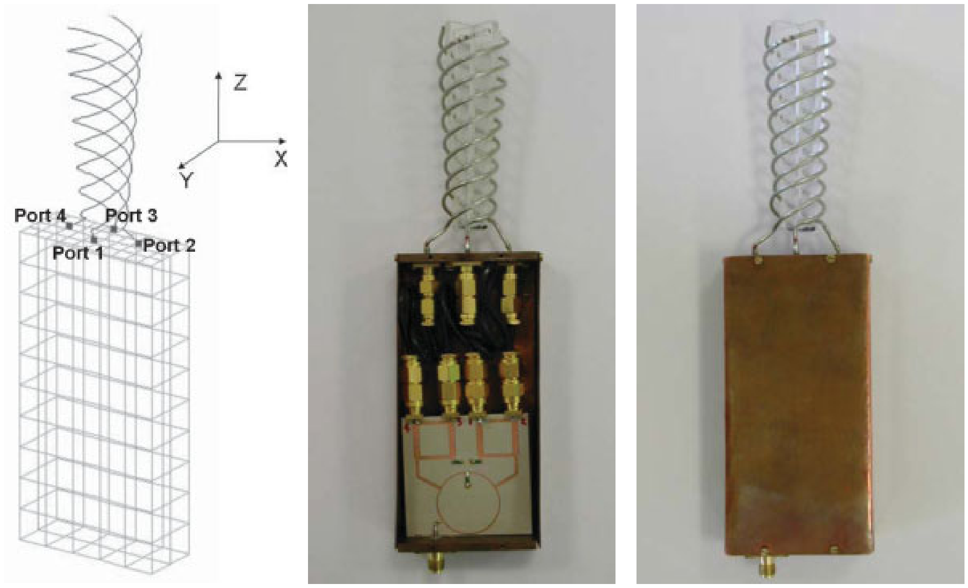
$$\mathrm{VSWR} = (1+\Gamma)/(1-\Gamma)\ \Gamma = |(Z_{in}-50)/(Z_{in}+50)|$$

VSWR is the voltage standing wave ratio, AR is the axial ratio, Z_{in} is the input impedance, Γ is the reflection coefficient and W_1 and W_2 are the weighting coefficients. The objective was to maximize F.

The GA was applied using the following procedure: The GA randomly chooses the initial population and then converts each antenna configuration to a file which can be read by NEC2. The NEC2 program is executed and the results will be fed back to GA for the evaluation process. This will continue till GA converges to an optimum solution.

3. ANTENNA DESIGN USING GA

In general, the proposed antenna is firstly tested on an infinite ground plane and then optimized further on small size handsets. The attained optimal antenna geometry and GA parameters including the handset are presented in Figure 1 and Table 1. The figure also shows the hybrid circuit used to correctly feed the four arms of the QHA antenna with equal amplitude voltages and four phases (these are 0°, 90°, 180°, and 270°) [10]. The maximum practical errors found on the amplitudes and phases of the hybrid were ±0.05 dB and ±1.5°, respectively, over 10%



(a) (b) (c)

Figure 1 Geometry of the proposed QHA antenna (a) The NEC2 model, (b) internal view of the completed assembly, (c) overall completed assembly. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

TABLE 1 Summary of GA Input Parameters, Antenna Variables and Best Solutions

GA parameters	QHA design on infinite ground: Parameters (m)	QHA design on infinite ground: Optimum values (m)	QHA design on the handset: Parameters (m)	QHA design on the handset: Optimum values (m)
Number of population size = 4	Pitch distance (0.01–0.04)	0.03998	Pitch distance (0.01–0.048)	0.04494
Number of parameters = 4	Axial length (0.05–0.12)	0.05649	Axial length (0.05–0.12)	0.05185
Probability of mutation =0.02	Radius at the bottom (0.005–0.01)	0.00982	Radius at the bottom (0.005–0.015)	0.01367
Maximum generation =50 (infinite ground), 250 (handset)	Radius at the top (0.01–0.02)	0.01871	Radius at the top (0.01–0.02)	0.01904
Number of possibilities=32768	Radius of wires	0.0005	Radius of wires	0.0005
			Distance above handset	0.005

relative bandwidth of 2.4 GHz. Table 1 presents the GA input parameters, their constraints and the optimal values for each specified parameter of the design geometry. These results include the study of the QHA on an infinite ground plane and a handset box. It has to be noted that the two weighting coefficients W_1 and W_2 are optimally found to be 0.5 and 0.75, respectively, for optimum design after a few tries, as illustrated in Table 2. It presents the comparative results of VSWR, AR, and Fitness as the values of the weighting coefficients are varied. Within the maximum number of generations, the values of maximum fitness function for QHA design reach about 1.03. Moreover, a comparison of maximum fitness versus generations of different combination choice of the two weighting coeffi-

TABLE 2 Comparative Results of VSWR, AR, and Fitness as the Values of the Weighting Coefficients Are Varied

Weighting (W_1, W_2)	0.2, 0.85	0.3, 0.75	0.4, 0.75	0.5, 0.75
VSWR	1.74531	1.66912	2.03473	1.49462
AR	0.92561	0.92665	0.98089	0.92493
Fitness	0.90064	0.87472	0.93266	1.0282

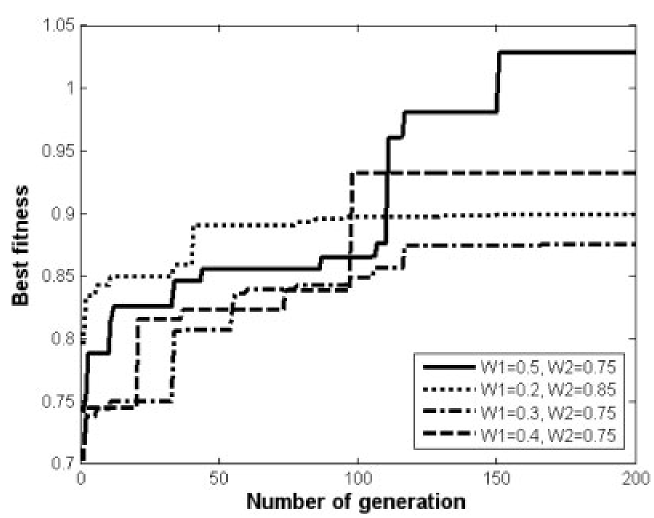


Figure 2 Maximum fitness versus generations (four populations in each generation)

cients is shown in Figure 2. The value of best fitness for the cost function tends to reach an optimum solution after around 150 generations. Figure 3 presents the progress of best fitness and average fitness against the number of generations for some selected values of weighting coefficients.

After achieving the first design goal on an infinite ground, the design of QHA with a small size handset was carried out. The handset dimensions for this study were selected to be 20 × 50 × 100 mm^2. The GA input parameters were kept unchanged, but some of their constraints and the maximum number of generations were adaptively altered for maximizing the cost function in turns of the VSWR and AR, as demonstrated in Table 1. It is notable that in order to ensure that the antenna is properly connected with the top plane of the handset, a wire with 5-mm length from each of the selected feeding points on the handset was added and then the antenna was designed and optimized on these extended wires. The maximum value of the cost function was found to be 1.12, using the same weight coefficients considered on an infinite ground.

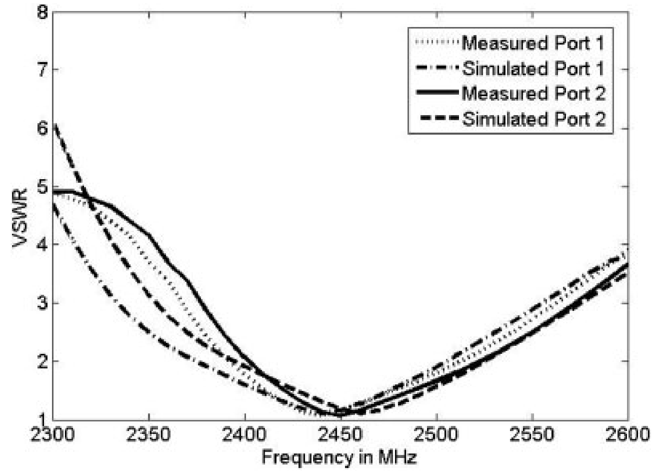


Figure 4 Computed and measured VSWR of ports 1 and 2 against the operating frequency

4. RESULTS AND DISCUSSION

Configurations of optimal proposed QHA antenna, with excellent VSWR and AR, were found within the maximum generations; antenna parameters of the best designs are shown in Table 1.

The voltage standing wave ratio (VSWR) at the input ports 1 and 2 (be noted ports 3 and 4 are similar) of the proposed circularly polarized antenna were calculated and measured over the targeted frequency band [11], i.e. ISM2400 band, from 2400 to 2485 MHz, as elucidated in Figure 4. The narrow bandwidth of the designed antenna bandwidth was not considered in the GA cost function, but the optimal antenna appears to have an excellent impedance matching that covers the bandwidth requirements at 2.4 GHz for satellite mobile communications. Both the simulated and measured VSWR are in good agreement.

Figure 5 illustrates the measured axial ratio of the proposed antenna against the elevation angle θ at 2350, 2400, 2420, and 2450 MHz for two vertical planes at constant $\Phi = 0°$ and $\Phi = 90°$. As can be observed, the proposed antenna shows ± 90° elevation angle variations for an axial ratio less than 4 dB. The observations confirm the superior circular-polarized characteristic for the proposed antenna over a wide elevation angle. Figure 6 depicts the far field patterns of the proposed antenna at 2400 and 2450 MHz for two planes similar to those plotted for the AR measurements. As can be observed, symmetrical and identical variations were obtained for all the radiation patterns. The maximum gain of the antenna is found to be around 6 dBi over the ISM2400 band.

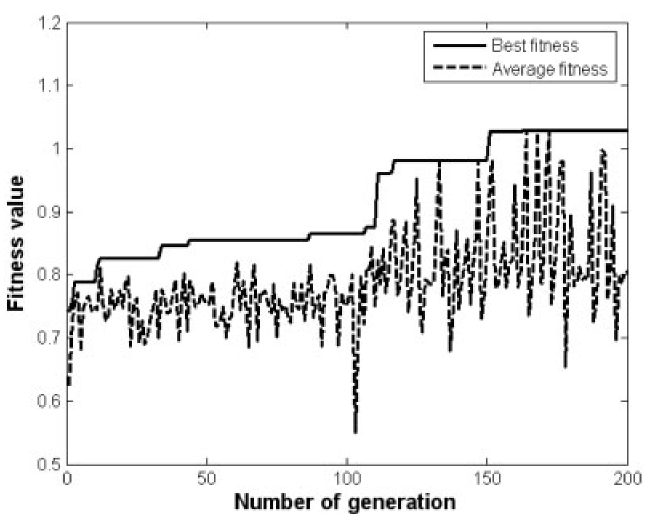


Figure 3 The progress of best fitness and average fitness for W_1 and W_2 are 0.5 and 0.75, respectively

5. CONCLUSION

An efficient GA optimization technique, for designing a circularly polarised QHA built on a small mobile handset, has been presented. The performance of the best selected antenna structure was validated and compared using a commercial EM simulator and measurement. The results confirm that an axial ratio of less than 4 dB over ± 90° elevation angle can be achieved with acceptable 6 dBi power gain. The GA has proven its advantage in quickly finding solutions for antenna designs.

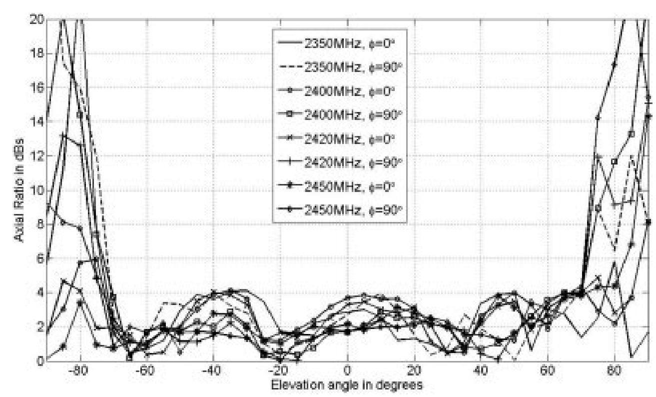


Figure 5 Measured axial ratios in dBs against the elevation angles for four different frequencies at two vertical cuts: $\Phi = 0°$ and $\Phi = 90°$

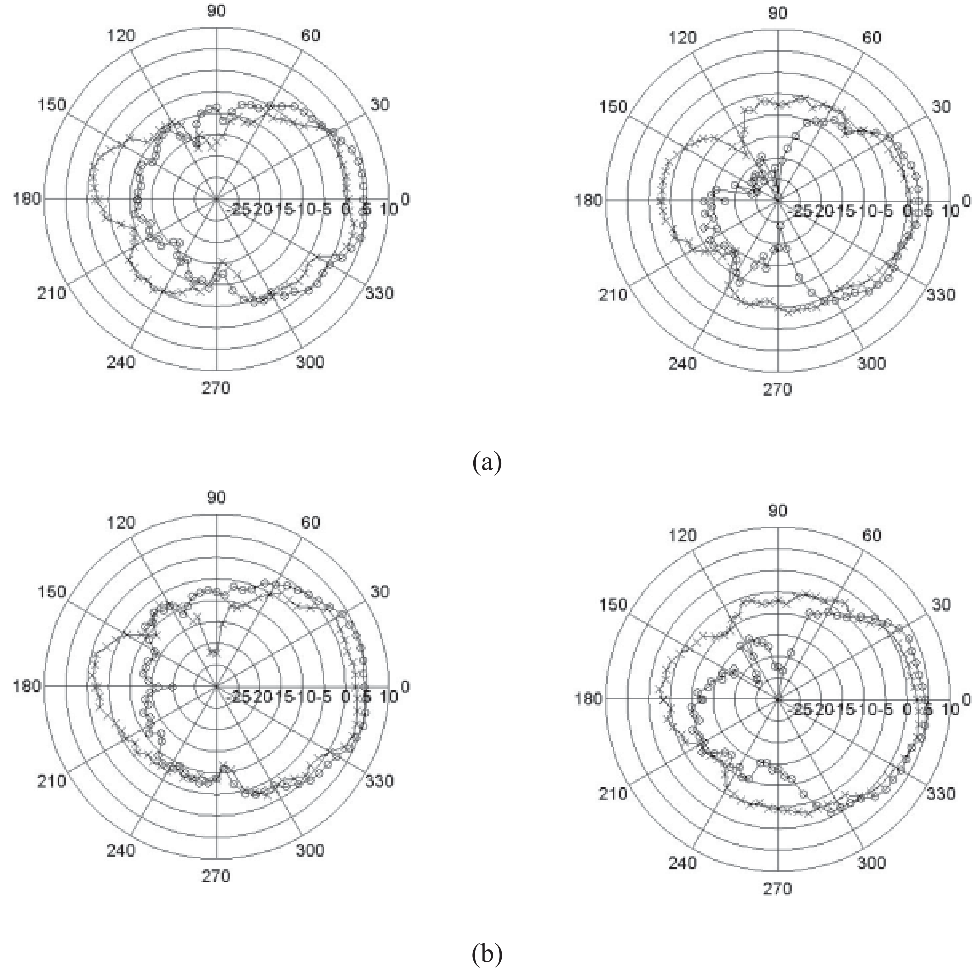


Figure 6 Measured gain radiation patterns of the proposed antenna at (a) 2400 MHz and (b) 2450 MHz, for two vertical planes $\Phi = 0°$ (left) and $\Phi = 90°$ (right). ‘x-x-x’ measured Cross-polar pattern; ‘o-o-o’ measured Co-polar pattern

REFERENCES

1. D.E. Goldberg, Genetic algorithms in search, optimization and machine learning, Reading, MA, Addison-Wesley, 1989.
2. J.M. Johnson and Y. Rahmat-Samii, Genetic algorithms in engineering electromagnetics, IEEE Antennas Propag Mag 39 (1997), 7–21.
3. E.E. Altshuler and D.S. Linden, Wire-antenna designs using genetic algorithms, IEEE Antennas Propag Mag 39 (1997), 33–43.
4. E.A. Jones and W.T. Joines, Design of Yagi-Uda antennas using genetic algorithms, IEEE Trans Antennas Propag 45 (1997), 1386–1392.
5. W.-C. Liu, Design of a CPW-fed notched planar monopole antenna for multiband operations using a genetic algorithm, IEE Proc Microwave Antennas Propag 152 (2005), 273–277.
6. P. Soontornpipit, C.M. Furse, and Y.C. Chung, Miniaturized biocompatible microstrip antenna using genetic algorithm, IEEE Trans Antennas Propag 53 (2005), 1939–1945, 2005.
7. R. A. Abd-Alhameed, M. Mangoud, P.S. Excell, and K. Khalil, Investigations of polarization purity and specific absorption rate for two dual-band antennas for satellite-mobile handsets, IEEE Trans Antennas Propag 53 (2005), 2108–2110.
8. D.L. Carroll, FORTRAN genetic algorithm Driver, Version 1.7, Download from: http://www.staff.uiuc.edu/~carroll/ga.html, 12/11/98.
9. G.L. Burke and A.J. Poggio, Numerical electromagnetics code (NEC)—method of moments, Lawrence Livermore Laboratory, Livermore, CA, 1981.
10. S.M. Daddish, R.A. Abd-Alhameed, and P.S. Excell, New designs for dual band antennas for satellite-mobile communications handsets, ACES J (Special Issue in Mobile Wireless Commun) 3 (2000), 248–258.
11. J.S. McLean, Balancing networks for symmetric antennas. II. Practical implementation and modelling, IEEE Trans Electromagn Compatibil 46 (2004), 24–32.

PERFORMANCE AND CAPACITY ANALYSIS OF 60 GHz WPAN CHANNEL

Suiyan Geng
Department of Radio Science and Engineering, Helsinki University of Technology (TKK), PO Box 3000, FI-02015 TKK, Finland;
Corresponding author: gsuiyan@cc.hut.fi

Received 15 February 2009

ABSTRACT: *In this work, the performance and capacity of both 60 GHz ultrawide-band (UWB) and multiple-in multiple-out (MIMO) channels are analyzed based on experimental channel models and specifications for millimeter-wave wireless personal area networks (WPANs). In the analysis of 60*