The University of Bradford Institutional Repository

Author(s): Zhou, D., Abd-Alhameed,R. A., See, C. H. and Excell, P. S.

Title: Novel Wide Harmonic Suppression Antenna Designed Using Adaptive Meshing and Genetic Algorithms.

Publication year: 2010

Conference title: Asia-Pacific Radio Science Conference, Toyama, Japan, Sept 2010.

Link to publisher's site: http://www.ap.ide.titech.ac.jp/ap-rasc10/

Citation: Zhou, D., Abd-Alhameed,R. A., See, C. H. and Excell, P. S. (2010). Novel Wide Harmonic Suppression Antenna Designed Using Adaptive Meshing and Genetic Algorithms. Asia-Pacific Radio Science Conference, Toyama, Japan, Sept 2010. ISBN 978-953-7619-76-3. Paper Number BEFKc:5.

Novel Wide Harmonic Suppression Antenna Designed Using Adaptive Meshing and Genetic Algorithms

D. Zhou*, R.A. Abd-Alhameed*, C.H. See* and P.S. Excell**
*Mobile and Satellite Communications Research Centre, University of Bradford
Bradford, West Yorkshire, BD7 1DP, UK
Email: {d.zhou2; r.a.a.abd; c.h.see2}@bradford.ac.uk
**School of Computing and Communications Technology, Glyndwr University
Wrexham, LL11 2AW, Wales, UK
Email: p.excell@glyndwr.ac.uk

Abstract—Microstrip patch antennas with harmonic suppression are designed and optimised, using a genetic algorithm and applying a novel adaptive meshing program to generate a wire-grid simulation. A coaxially-fed air-dielectric patch antenna design with a folded patch was investigated. It was confirmed that antennas with excellent performances could be designed by this method.

1. Introduction

Harmonic suppression antennas (HSAs) are used to suppress power radiation at harmonic frequencies from active integrated antennas. An antenna that presents a good impedance match at the fundamental design frequency (f_o) and maximised reflection at harmonic frequencies is said to be a harmonic suppression antenna. In addition, the input impedance of any well-designed HSA was also required to possess a minimised resistance at the harmonic frequencies and hence will be largely reactive. Several techniques have been proposed to control such harmonics, such as: shorting pins, slots or photonic bandgap structures [1-3]. It was found that most of those published work for modified patch antennas featured for harmonic suppression have been based on a specific reference antenna, suggesting that the proposed techniques for rejecting harmonic radiation have certain constraints applied on them.

There is thus a motivation to develop a new approach to design HSA for active integrated antenna type of application. In this paper, a numerical technique in designing and optimising HSA is proposed using surface adaptive meshing driven by a genetic algorithm (GA). The design of coaxially-fed air-dielectric microstrip harmonic-rejecting patch antennas with a folded patch was investigated by this method.

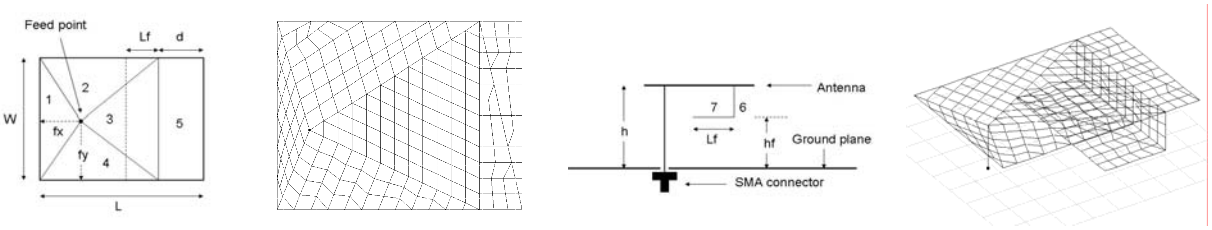
2. Genetic algorithm and adaptive meshing program

An approach of using GA in cooperation with an electromagnetic simulator has become increasingly popular technique in antenna development and optimisation. The benefit of applying GA is that they provide fast, accurate and reliable solutions for antenna design problems [4]. Genetic algorithm driver, written in FORTRAN, was adopted in this work in conjunction with the industry-standard NEC-2 Fortran source code, which was used to evaluate the randomly generated antenna samples. In GA optimisation scenario, genes are generally the code representation of the optimization parameters. A string of these genes produces a chromosome: for this optimisation, real-valued GA chromosomes were used. A set of randomly-generated solutions in the form of chromosomes is formed as a population. The optimization iterations in GA are called generations. Initially, the algorithm randomly initiates its population and converts the parameters of the initiated individuals into a file in a card format which can be called by NEC-2 to determine the performance of these individuals. The results from NEC-2 are fed again to the GA engine to evaluate individual fitness if the maximum value is obtained for convergence, if otherwise the whole process is repeated until optimal results are produced.

The adaptive meshing program is written in FORTRAN by the present authors and added as a subroutine to the GA driver, with the primary objective of simulating air-dielectric planar microstrip patch antenna designs, using wire-grid models simulated with the NEC-2 code in cooperation with a genetic algorithm [5]. This subroutine provides the suitable link of the GA cost function to the NEC-2. Basically, the antenna under optimization needs to be defined by a number of parameters that can define the antenna configuration. Subsequently, the antenna geometry is adaptively divided into optimum numbers of trilateral and quadrilateral polygons by the code user. Each polygon can be represented using either three or four nodes. Each node is specified by its x, y and z co-ordinates subject to the defined antenna parameters. Then, the fictitious wire boundaries of these polygons can be optimally segmented to a pre-set segment length and connected to each other using a designated algorithm, this also creating a mesh of wires within the polygon to make it approximate to the behaviour of sheet metal. The method avoids closely separated wire segments, in which the minimum separation distance considered is four times the wire radius. It also provides the equivalent surface areas between the wire grid model and actual antenna geometry.

3. Antenna modelling and computation

The proposed antenna geometry for harmonic suppression, having a folded patch extended underneath the main patch, is shown Fig 1. For the design proposal the antenna is subdivided into four trilaterals and three quadrilaterals (including folded patch), as illustrated in Fig 1 (a) and (c). This proposal was requiring eight parameters to be defined. Fig 1 (b) and (d) demonstrate the top view and 3D view of the adaptive wire grid segmentation results.



(a) (b) (c) (d)

Figure 1. The proposed antenna geometry with a folded patch and resulted wire-grid meshing: (a) Top view subdivision of the antenna geometry used for adaptive meshing using GA; (b) Top view of resulted wire mesh used for Fig. 1 (a); (c) Side view of the antenna geometry of Fig. 1 (a); (d) 3D view of the resulted wire mesh using GA.

Table 1 presents the GA input parameters in which the possible range of parameters magnitudes were shown. In this study, the fundamental (f_o=2.45 GHz), second and third harmonic frequencies were considered inside the GA cost function. The randomly generated antenna configurations were evaluated for maximum fitness using the following cost function:

$$F = w_1 \frac{1}{VSWR(f_o)} + \sum_{i=2}^{n} w_i \left|\Gamma(if_o)\right| \qquad (1)$$

Where F is the fitness of the cost function; $n = 3$; W_1, W_2 and W_3 are the weight coefficients of the cost function and they were optimally found to be 0.4, 0.4 and 0.6 after a few attempts. The geometry configuration of the optimal antenna was found within the maximum generations and it is presented in Fig. 1 (d), where the white coloured-grid surface represents the infinite ground plane.

Table 1: GA input parameters, antenna variables and best solutions for the proposed design.

GA parameters	Air-dielectric folded patch antenna design	
	Parameters (m)	Optimal (m)
	Antenna length (L) (0.03-0.06)	0.04316
No. of population size = 4,	Antenna width (W) (0.02-0.06)	0.03006
No. of genes = 8,	folded wall position (d) (0.005-0.015)	0.00748
Probability of mutation = 0.02,	Antenna height (h) (0.004-0.01)	0.00989
Maximum generation = 500,	Extend folded wall length (Lf) (0.005-0.015)	0.01327
No. of possibilities = 32768,	Extend folded wall height (hf) (0.001-0.0035)	0.00159
	Feeding point at x-axis (fx) (0.004-0.015)	0.00571
	Feeding point at y-axis (fy) (0.004-0.025)	0.01392

4. Results and Discussion

For validation, prototype of the GA-optimised HSA with folded patch was fabricated and tested (see Table 1 for important dimensions for this optimal antenna). The ground plane size was 140 mm x 140 mm and this relatively large size is for the purpose of eliminating effect of the finite ground plane. The return loss was validated and measured result compared with calculations (frequencies from 2 to 9 GHz) is shown in Fig. 3. As can be seen, the results for rejection levels of 2nd and 3rd harmonics were quite encouraging and no other resonances or ripples were found at the harmonic frequency bands. The measured resonant frequency of the GA-optimised antenna was found 2.43 GHz.

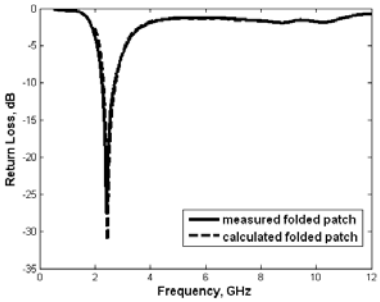


Figure 3. Comparison of the measured and calculated proposed antenna return loss.

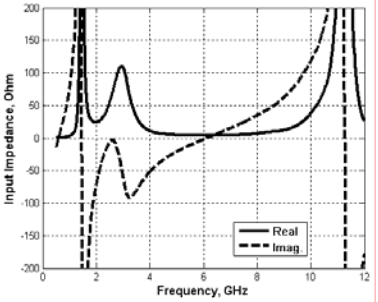


Figure 4. Measured input impedance of the GA-optimised HSA.

The measured input impedance over the frequency band of 0.5 to 12 GHz is shown in Fig. 4. It can be seen that the real part of the input impedance of the proposed antenna is close to zero for a wide frequency band around the second and third harmonic frequencies. This is also indicating that the influence of the reactive effects to harmonic termination at harmonic frequencies are realised. Measurements of radiation patterns of the prototype antenna were also carried out in a far-field anechoic chamber. The radiation patterns in two principle planes (i.e. zx plane and zy plane) for the GA-optimized HSA at fundamental, second and third harmonic frequencies were measured. The measured results were presented in Fig. 5, in which the second and third harmonic radiations of the proposed HSA are found less than 19 dB and 13 dB for the zx plane and 10 dB and 9 dB for the zy plane respectively. The measured maximum gain of the GA-optimised antenna was found to be 5 dB.

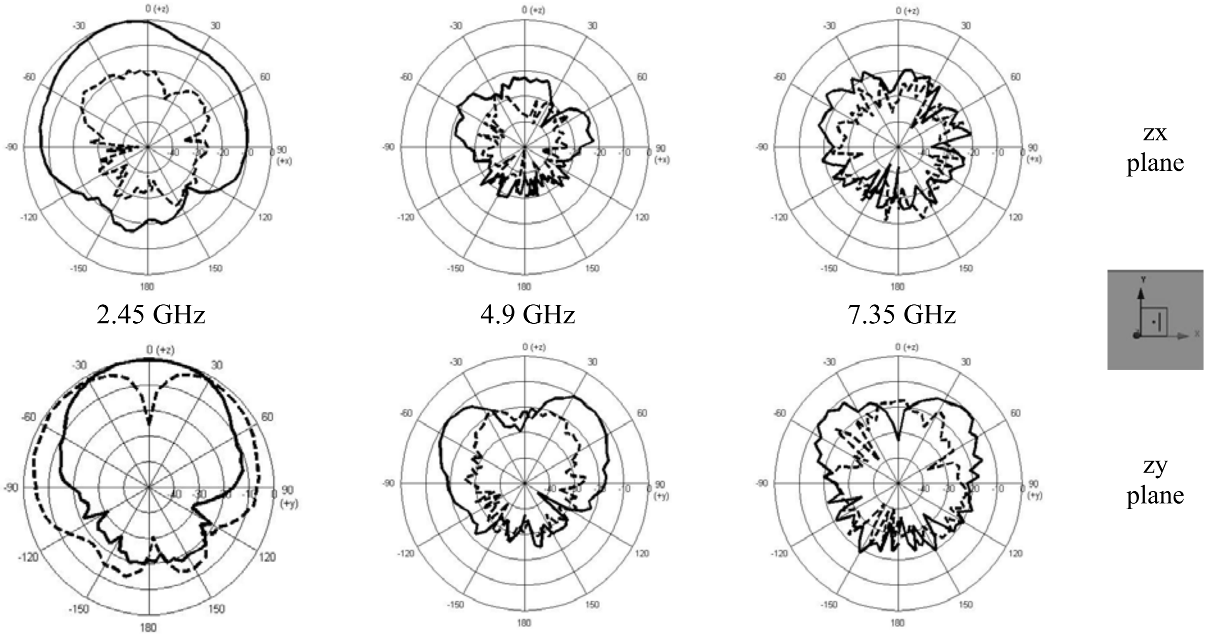


Figure 5: Measured radiation patterns of the proposed GA-optimized HSA for 2.45 GHz, 4.9 GHz and 7.35 GHz at: '——' measured E_θ; '- - - -' measured E_ϕ.

5. Conclusions

A novel technique for the design and optimisation of patch antennas for harmonic suppression has been presented, using surface adaptive meshing of wire-grid representations of sheet conductors, optimised by use of genetic algorithms. A novel microstrip patch antennas, for which the second and third harmonics were mostly suppressed, have been successfully developed by this method. The results of the optimum design of the proposed antenna exhibit an excellent harmonic suppression. The presented example shows the capability of the proposed program in antenna design using GA.

References

1. V. Radisic, S.T. Chew, Y. Qian, and Tatsuo Itoh, "High efficiency power amplifier integrated with antenna", *IEEE Microw. Guided W.*, vol. 7, no. 2, pp. 39-41, February 1997.
2. H. Kim, K.S. Hwang, K. Chang and Y.J. Yoon, "Novel slot antennas for harmonic suppression", IEEE antennas and wireless components letters, 14, no. 6, pp. 286-288, 2004.
3. Y.J. Sung and Y.-S. Kim, "An improved design of microstrip patch antennas using photonic bandgap structure", *IEEE Trans. Antennas Propag.*, 53, no. 5, pp. 1799-1804, 2005.
4. D Zhou, RA Abd-Alhameed, CH See, PS Excell, FY Hu, K Kahlil and NJ McEwan, "Quadrifilar helical antenna design for satellite-mobile handsets using genetic algorithms", *Microwave and Optical Technology Letter*, Vol. 51, Iss. 11, pp. 2668-2671, November 2009.
5. RA Abd-Alhameed, D Zhou, CH See, and PS Excell, "A wire-grid adaptive meshing program for microstrip-patch antenna designs using a genetic algorithm", *IEEE Antennas and Propagation Magazine*, Vol. 51, Iss. 1, pp. 147-151, February 2009.