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The Calculations of S_{11} and SAR values of a Wearable Monopole Antenna with FDTD Technique

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Abstract

The calculation of S_{11} and specific absorption rate (SAR) of a wearable monopole antenna is presented using finite difference time domain (FDTD) technique. The antenna under investigation is a multiband antenna with four monopoles which are fed by a coplanar waveguide. The monopoles of the antenna are modeled using staircase scheme. In this work, non-uniform sampling of the FDTD cells has been used to accurately model the individual monopole of the antenna. The calculated S_{11} and SAR values of the antenna using FDTD method are compared with HFSS and measured results. A satisfactory agreement between the FDTD and HFSS values of S_{11} and SAR has validated the code developed using FDTD technique.

Keywords: *Finite difference time domain technique, wearable monopole antenna, reflection coefficient, SAR, tissue phantom.*

1. Introduction

With the understanding of the importance, flexibility and applications of the FDTD technique, researchers have exploited the FDTD scheme for the analysis of several antennas [1-5, 8]. This scheme's simple and flexible implementation in antenna analysis has provided platform to understand the behavior of the interaction between electromagnetic wave, patch of the antenna, substrate of the antenna and ground plane of the antenna.

SAR is an important parameter for wearable antennas [6, 8-12]. With this perception, the S_{11} and specific absorption rate of a wearable multiband antenna with four monopoles are calculated and analyzed using finite difference time domain technique and results are presented.

2. FDTD Modeling of the Wearable Monopole Antenna with Multiband Operation

The antenna under investigation is actually designed and presented in [6]. The main structure of the wearable antenna [6] under investigation is shown in Figure 1. It is a wide CPW fed multiband monopole antenna designed for wearable applications [6]. All the dimensions of this antenna are illustrated in [6]. Only major dimensions of this antenna are shown in this work. The thickness of the handmade substrate is 1.0 mm. The dielectric constant of the polyester substrate is about 1.39 [6]. The major dimensions of the antenna are listedin Table I. The remaining dimensions are not mentioned as they are available in [6].

Table I. Major dimensions of antenna under investigation [6].

Dimension	Value (mm)
L	85.0

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W	45.5
L_T	38.5
W_T	3.15
L_g	40.0
W_g	19.4
W_1	6.3
g	0.2

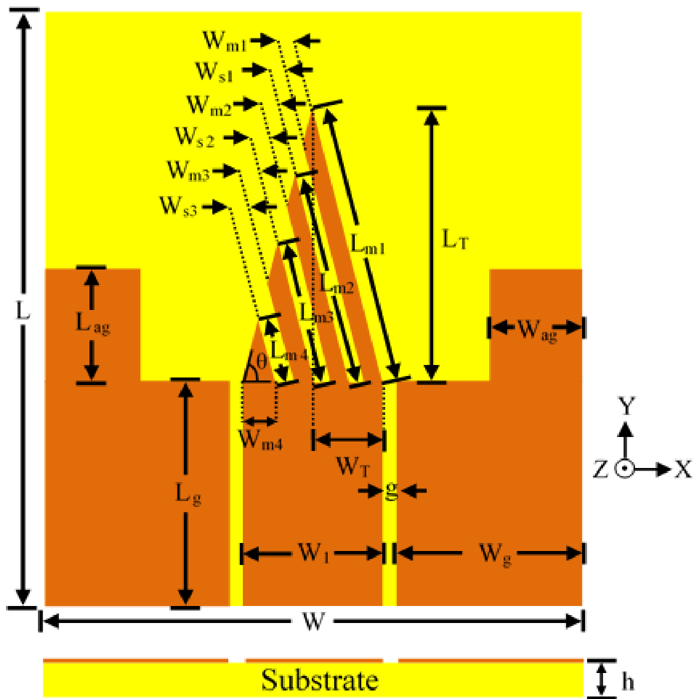

Figure 1. Geometry of the wearable monopole antenna under investigation for S_{11} and SAR calculations with finite difference time domain technique [6].

To completely and precisely model the monopole antenna for S_{11} and SAR calculations, the number of FDTD cells employed in *x*, *y* and *z* directions are presented in Table II.

Table II. Number of FDTD cells employed

Parameter	**Number of FDTD Cells**		
	x- direction	**y-direction**	**z-direction**
S_{11}	256	205	20
SAR	400	400	42

2.1 Calculation of S_{11} with FDTD Technique

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For S_{11} calculations, the FDTD modeling using non-uniform cell sizes is presented in Figure 2. In *x*-direction, the number of FDTD cells for monopoles and their size are presented in Table III. Similarly, the modeling of the monopoles along *y*-direction is done using multiple cell sizes and is illustrated in Table IV. Nearly seven different sizes of cells have been used along *y*-direction. The straight lengths of four monopoles $m_1/m_2/m_3/m_4$ of antenna are 38.5/30.35/20.47/8.55 mm, respectively. For ground plane, 40 cells in *x*-direction and 80 cells in *y*-direction are used. The cell sizes for ground plane are 0.485 mm and 0.5 mm in *x* and *y* directions, respectively. For extended grounds, 25 cells in *x*-direction and 18 cells in *y*-direction are used. The cell sizes for extended grounds are 0.485 mm and 0.5 mm in *x* and *y* directions, respectively.The snapshot of the FDTD technique simulation for the calculation of S_{11} and SAR parameters is illustrated in Figure 3. Figure 3 presents the distribution of the $E_z$part in the monopole antenna after 6000 time steps.

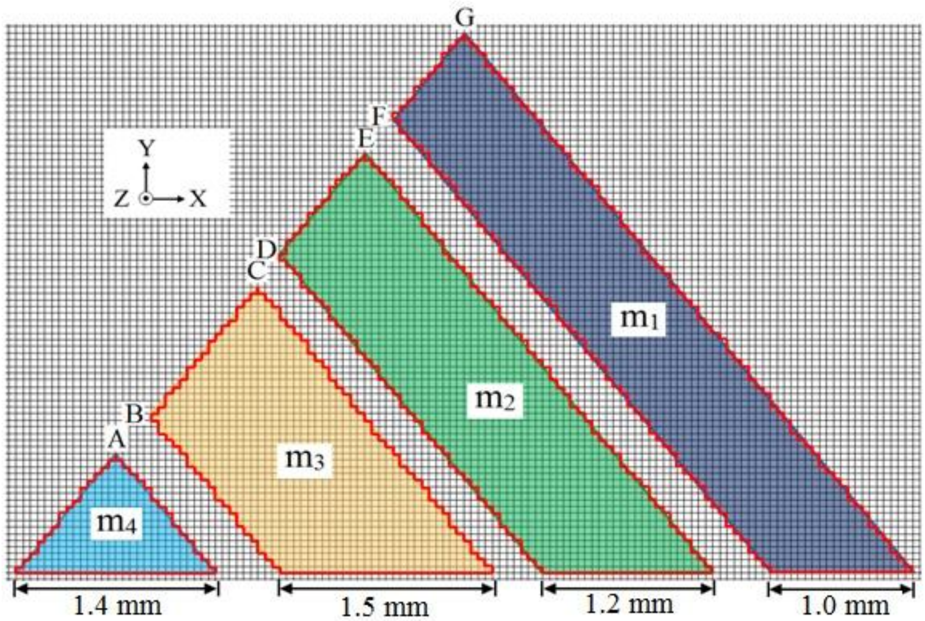

Figure 2. FDTD technique based monopole modeling.

Table III. Number of cells with size used in x-direction for monopoles.

Size (mm)	Number of FDTD cells used in *x*-direction			
	m_4	**m_3**	**m_2**	**m_1**
$\Delta x = 0.05$	28	30	24	20

Table IV illustrates the number of FDTD cells employed along *y*-direction. Total cells used for each monopole can be calculated from Table IV. The estimated S_{11} using FDTD technique is presented in Figure 4. The S_{11} calculated with FDTD technique is compared with measured and HFSS results in Figure 4. The four resonant frequencies calculated using FDTD technique for the antenna under investigation are about 1300 MHz, 2520 MHz, 3760 MHz and 4960 MHz, respectively

2.2 SAR calculation with FDTD Technique

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The distance of 0.5 mm is considered between the antenna and tissue phantom [6] for SAR calculations. The permittivity, conductivity and density of the skin, fat and muscle layers are considered same as described in [6]. SAR is calculated by using the expression given in [8]. The SAR values estimated using FDTD technique are compared with HFSS results and are presented in Table V.

Table IV. Number of cells with sizes used in *y*-direction for monopoles.

Size (mm)	**Number of FDTD cells used in *y*-direction**						
	m_4 **(up to A)**	m_3 **(up to B)**	m_3 **(up toC)**	m_2 **(up to D)**	m_2 **(up to E)**	m_1 **(up to F)**	m_1 **(up toG)**
Δy = 0.5	17	17	17	17	17	17	17
Δy = 0.05	01	01	01	01	01	01	01
Δy = 0.5	-	05	05	05	05	05	05
Δy = 0.25	-	01	01	01	01	01	01
Δy = 0.5	-	-	18	18	18	18	18
Δy = 0.17	-	-	01	01	01	01	01
Δy = 0.5	-	-	-	04	04	04	04
Δy = 0.56	-	-	-	01	01	01	01
Δy = 0.5	-	-	-	-	14	14	14
Δy = 0.32	-	-	-	-	01	01	01
Δy = 0.5	-	-	-	-	-	04	04
Δy = 0.04	-	-	-	-	-	01	01
Δy = 0.5	-	-	-	-	-	-	12
Δy = 0.11	-	-	-	-	-	-	01

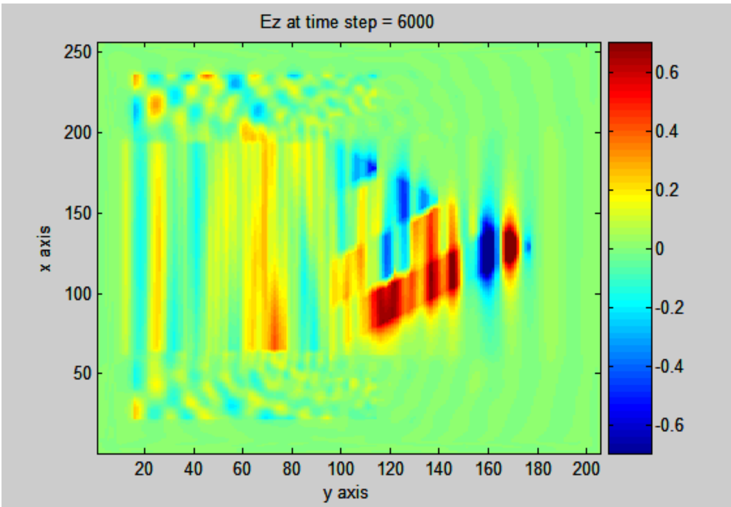

Figure 3. The distribution of the Ez component in the monopole antenna after 6000 time steps of FDTD technique simulation.

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TABLE V. SAR values calculated with FDTD technique and their comparison with HFSS results [6]

Simulation Frequency (GHz)	SAR (W/Kg)	
	HFSS	FDTD Technique
1.78	0.2293	0.0255
2.40	0.3892	0.1029
3.46	0.4640	0.1652
5.26	0.2535	0.5722

For the first three simulation frequencies, the values of specific absorption rate estimated using FDTD technique aresmaller than the SAR values computed with High Frequency Structure Simulator (HFSS).

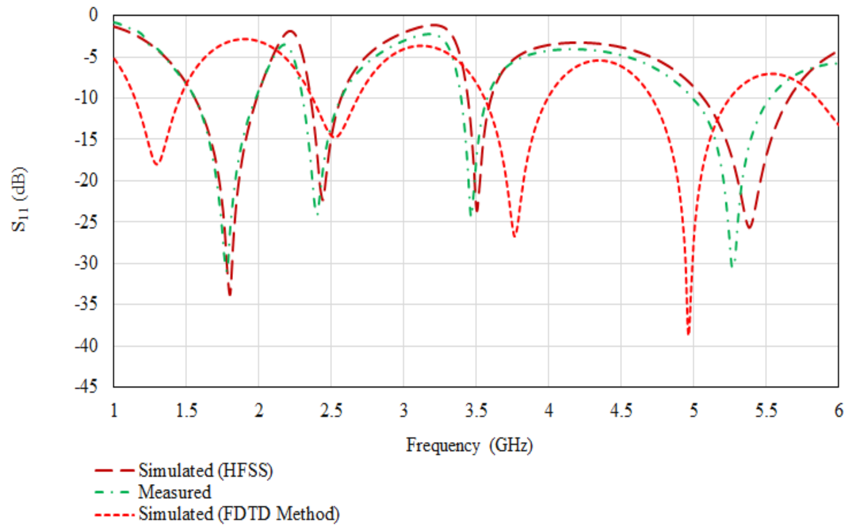

Figure 4. S_{11} calculated using FDTD technique and compared with HFSS and measured results [6].

3. **Conclusion**

The FDTD scheme has been used to successfully calculate the reflection coefficient and specific absorption rate of the antenna under investigation. A good agreement between FDTD technique and HFSS results have validated the code developed for investigation of the CPW fed multiband monopole antenna.

4. **Acknowledgment**

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