

Milli-Bend Analysis along the Width of a Wearable Antenna using FDTD Technique

Danvir Mandal¹ and S. S. Pattnaik²

¹ Lovely Professional University, Phagwara, Punjab (India) - 144411

¹ IK Gujral Punjab Technical University, Kapurthala, Punjab (India) -144603

² National Institute of Technical Teachers Training and Research, Chandigarh (India) -160026

Abstract

Milli-bends in the direction of the width of the wearable patch antenna are modeled and analyzed using Finite Difference Time Domain (FDTD) technique. Two milli-bends are considered and modeled along the width of the wearable antenna. Using staircase technique, first bend is modeled in the middle of the antenna where as the second bend is modeled in the right side of the antenna. The change in the input impedance and reflection coefficient due to the presence of milli-bends at the two resonant frequencies is reported and presented.

Keywords: FDTD technique, milli-bends, reflection coefficient, input impedance, wearable antenna.

1. Introduction

For the last few decades, the Finite Difference Time Domain (FDTD) method has been used rigorously by the antenna designers in the performance investigation of antennas [1-6, 12]. The FDTD method is a flexible technique which can be used to model almost any kind of antenna [2-7, 12]. Further, the modeling of all types of antenna feeding systems is possible by FDTD technique. In recent years, wearable antennas have become a popular choice among researchers and designers. For any wearable antenna, the bending analysis is one of the most important investigation and is directly associated with the design and development procedure [8-12].

Many researchers in past have presented the bending analysis of different wearable antennas [8-11]. The effect of milli-bends on input impedance and reflection coefficient is presented in [6, 7]. In [6, 7], the milli-bends are considered in the direction of the length of the antenna. The bends in the direction of the length of the antenna directly affect the electrical length of the antenna and hence change the input impedance and reflection coefficient at the resonant frequencies. In this work, the effect of milli-bends considered in the direction of the width of the wearable patch antenna are analyzed and results are presented. The milli-bends are modeled using the staircase approach in FDTD technique.

2. FDTD Technique and Specifications

The set of discrete equations employed in the FDTD method for the computation of variety of parameters is given as [2]:

$$H_x|_{i,j,k}^{n+1/2} = H_x|_{i,j,k}^{n-1/2} + \frac{\Delta t}{\mu\Delta z} (E_y|_{i,j,k}^n - E_y|_{i,j,k-1}^n) - \frac{\Delta t}{\mu\Delta y} (E_z|_{i,j,k}^n - E_z|_{i,j-1,k}^n) \quad (1)$$

$$E_z|_{i,j,k}^{n+1} = E_z|_{i,j,k}^n + \frac{\Delta t}{\epsilon \Delta x} (H_y|_{i+1,j,k}^{n+1/2} - H_y|_{i,j,k}^{n+1/2}) - \frac{\Delta t}{\epsilon \Delta y} (H_x|_{i,j+1,k}^{n+1/2} - H_x|_{i,j,k}^{n+1/2}) \quad (2)$$

Only one component of electric and magnetic fields are illustrated. The remaining components are presented in [2]. Total number of cells and cell sizes used for FDTD modeling of antenna, as used in [2], are presented in Table I.

Table I. Numbers of cells and cell sizes used for FDTD modeling of antenna [2]

Axis direction	No. of FDTD cells	FDTD cell size (mm)
x-direction	62	0.389
y-direction	120	0.4
z-direction	20	0.265

The value of the time step used in simulation is 0.370 picoseconds. The difference between reference plane and patch edge is $45\Delta y$. The standard Gaussian pulse is used for the excitation of the antenna. The PML and source used in this work are similar to that used in [6] and [7].

3. Milli-Bends Modeling in Wearable Antenna

To analyze the effect of milli-bends in the direction of the width of the antenna, patch antenna presented in [2] is used. The modeling of the milli-bends in the direction of the width of the antenna is illustrated in Figure 1. The substrate of the antenna is considered flexible with the same specifications as given in [2]. The same antenna has been used in [6, 7] for the investigation of the milli-bends in the direction of the length of the antenna.

The numbers of FDTD cells used for the modeling of milli-bend B1 and B2 are presented in Table II. Bend is not considered in the side of micro-strip line as it will hinder the proper excitation of the antenna.

Table II. Numbers of cells used for FDTD modeling of milli-bends

Bend	No. of FDTD cells			
	x-direction	y-direction	z-direction	Bending angle
B1	10	120	8	33.524°
B2	10	120	8	33.524°

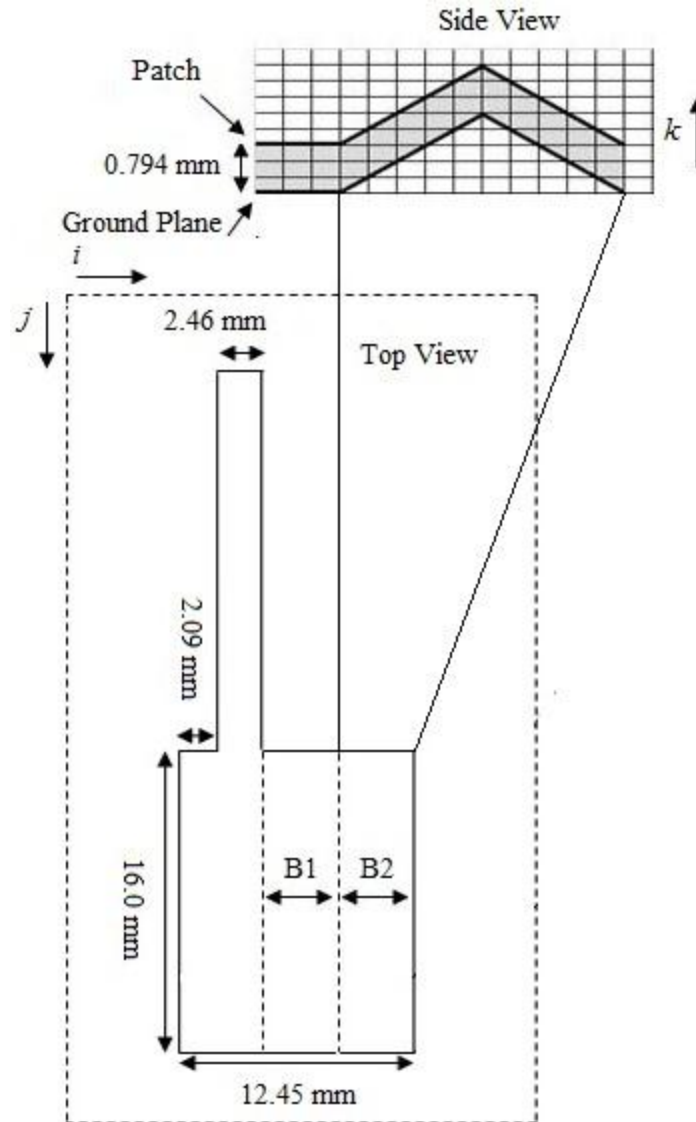


Figure 1: Milli-Bends Modeling in Antenna

4. Results

The reflection coefficients and input impedances (real and imaginary parts) of the antenna for two bending cases are compared with the results of normal antenna and are illustrated in Figures 2, 3 and 4. The computed numerical values of reflection coefficient and input impedance (real and imaginary) at two resonant frequencies of the antenna for various cases are compared and presented in Table III.

The comparison of the results revealed that due to milli-bend B1, the value of the reflection coefficient at 7.471 GHz increased due to the decrease in the value of the imaginary part of the input impedance, whereas the value of S_{11} decreased at 18.390 GHz due to decrease in the real part and increase in the imaginary part of the input impedance. Similarly, the S_{11} increased to -9.2197 at 7.126 GHz due to the decrease in the value of the imaginary part of the input

impedance. The value of the S_{11} at 18.505 GHz increased due to increase in the value of the real part of the input impedance.

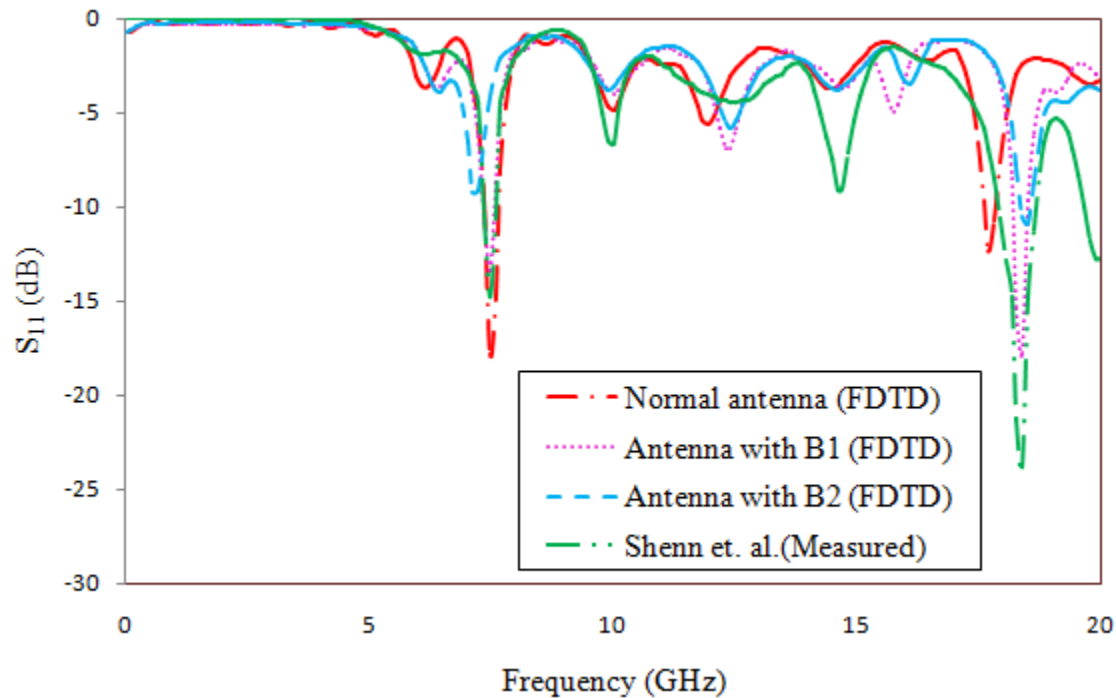


Figure 2. Comparison of reflection coefficients for various cases

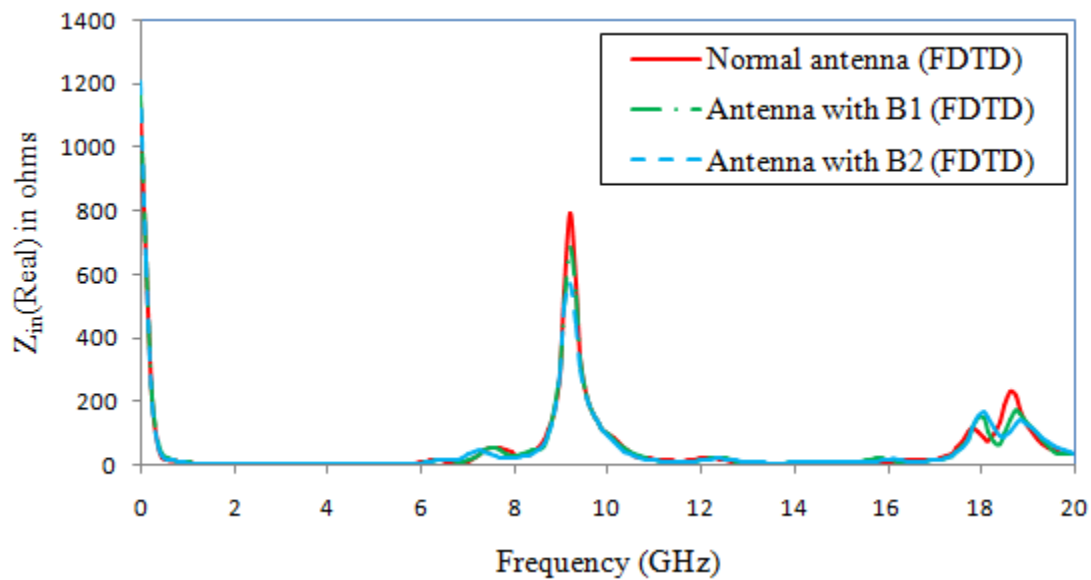


Figure 3. Comparison of real part of input impedance

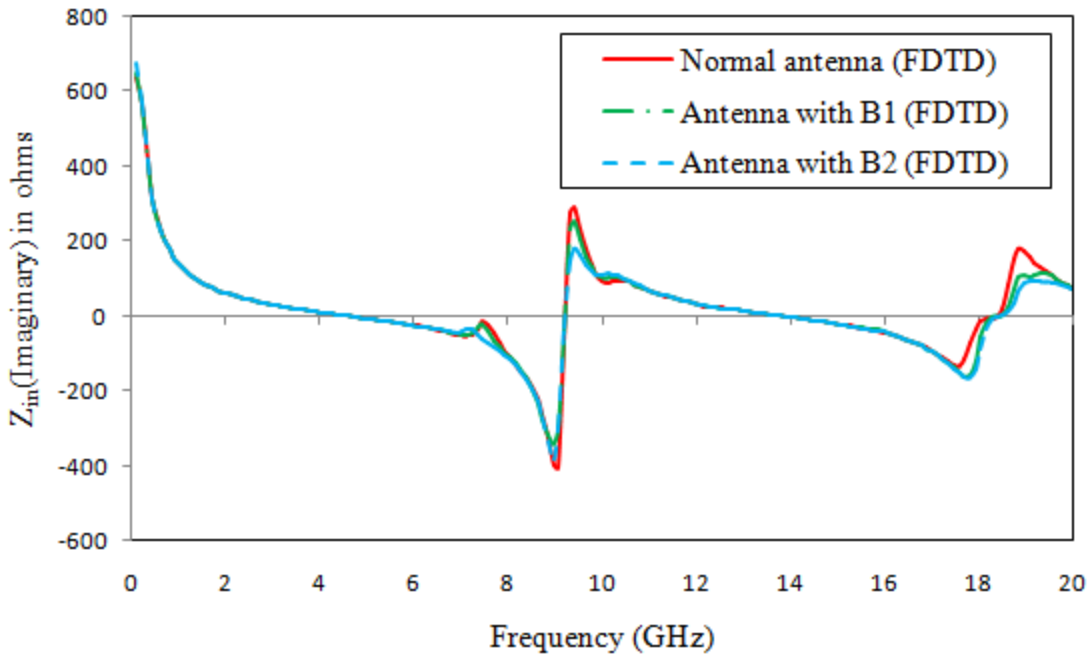


Figure 4. Comparison of imaginary part of input impedance

Table III. Comparison of S_{11} , Z_{in} (real) and Z_{in} (Imaginary)

Antenna Case	Frequency (GHz)	S_{11} (dB)	Real part of Z_{in} (ohms)	Imaginary part of Z_{in} (ohms)
Normal antenna	7.471	-17.838	53.73	-15.44
	17.701	-12.364	104.24	-114.75
Antenna with B1	7.471	-13.427	53.90	-22.31
	18.390	-17.775	64.83	-0.32
Antenna with B2	7.126	-9.2197	43.30	-33.65
	18.505	-10.872	89.88	3.32

5. Conclusion

Two milli-bends are modeled along the width of the antenna [2] and results for reflection coefficient and input impedance are compared and presented. The presence of milli-bends along the width of the antenna severely affects the performance of the antenna, same as they do in the case when they are present along the length of the antenna [6, 7]. The main effect of the presence of the milli-bends in a wearable antenna is the change in the resonant frequency and corresponding change in the S_{11} and Z_{in} , which is reflected in this work.

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