Conjointly Electromagnetic Simulations for Bended Microstrip Antenna Designs

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***Abstract*—Investigative electromagnetic (EM) simulations for bended antenna designs, also used for wearable devices, plays an important role in the design process. The simulation for conformal antennas is time consuming also considering the effects of the presence of the feeding/beamforming network on the antenna performances. To tackle this drawback, a new simulation environment is created, where Keysight ADS tool is employed for modeling the initial microstrip antenna of which shape is determined using a bottom-up optimization (BUO) method. The employed BUO in the ADS environment significantly helps the designer in generating the antenna geometries that exhibit the required performances in terms of bandwidth and radiation patterns. Afterwards, the CST Microwave Studio (Dassault Systèmes) is used for bending the previously designed flat microstrip antenna, and accurately evaluate its performances by numerical simulations. To verify the efficiency of the proposed methodology, one bended microstrip antenna in the frequency band of 8.8-9.4 GHz is designed and the radiation pattern responses are depicted.**

***Index Terms*—Bended microstrip antenna, bottom-up optimization (BUO), CST Microwave Studio tool, electromagnetic (EM), keysight ADS.**

I. Introduction

Next generation networks, including sixth generation (6G) networks are developing day by day; hence the need of high performance antennas are increasing exponentially [1], [2]. Microstrip antennas prove their beneficial aspects in the telecommunication area as they are easy to be fabricated and have acceptable performances in the required bandwidth [3]. These types of antennas are friendly in bending where the radiation characteristics can be importantly enhanced. What is the big challenge in the bended antennas, is the time consuming electromagnetic (EM) simulations leading to generate ready-to-fabricate layouts.

The electronic design automation (EDA) tool as ANSYS High-Frequency Structure Simulator (HFSS) and CST Microwave Studio (Dassault Systèmes) are beneficial in antenna designs; however the EM simulations are lasting long. One of the idea for reducing the time consuming EM simulation is to combining the Keysight ADS with the CST Microwave Studio suite. As presented in [4], by jointly using various EDA tools, the design of complex circuits can be easier than the traditional ones. Applying hierarchical methods such as bottom-up optimization (BUO) during the tool combinations, can help developing the antennas in an effective way [5].

In order to achieve high performance antennas in terms of radiation patterns (RPs) and to prepare wearable devices, in some cases it is preferred to bend the antennas [6], [7]. Hence, this work devotes to present an effective methodology of designing bended microstrip antennas. It presents a new method of designing such conformal antenna where the time consuming EM simulation effort can be substantially reduced. The presented algorithm is divided into two phases that are sequentially applied. In the first phase, the BUO method is employed in the Keysight ADS for modeling the configuration of the microstrip antenna and also considering the initial achieved antenna's specifications. If these outcomes are suitable, the generated layout in ADS is transferred into the CST environment. Afterwards in the second phase, the microstrip antenna is bended in the CST tool where the EM-simulations are also performed and the final post-layout is prepared.

This paper is organized as follows: Sec. II presents the methodology for designing bended microstrip antennas. The simulated results of designed antenna are presented in Sec. III. Finally, Sec. IV presents the conclusion of this work.

II. Antenna Development

This section presents in detail the summary of the proposed methodology for firstly configuring the microstrip antenna and then bending it. The proposed methodology is based on the combination of Keysight ADS and CST tools, where the ADS is used for modeling the antenna and the CST is employed to build the antenna geometry and bend it, as well as performing the final EM-simulations, and generating the ready-to-fabricate layout.

A. Configuring microstrip antenna using the BUO method, in the ADS environment

Providing an accurate configuration of a microstrip antenna, exhibiting targeted output responses, requires considerable effort. To alleviate it, in this case, we employ a hierarchical BUO method for generating the initial geometry of the antenna. This optimization starts with one transmission line (TL). Then the number of TLs is sequentially increased and their shape is modified until the appropriate results from the designer's point of view are obtained.

Figure 1 presents a brief overview around the BUO method that is used for generating the geometry of the antenna. The simulation environment for this phase of the methodology is preferred to be in Keysight ADS, as in this framework there exists an improved TL library [8]. Any TL contains two design parameters as width ('w') and length ('L'); the related values of each single TL are achieved using the random iteration optimization.

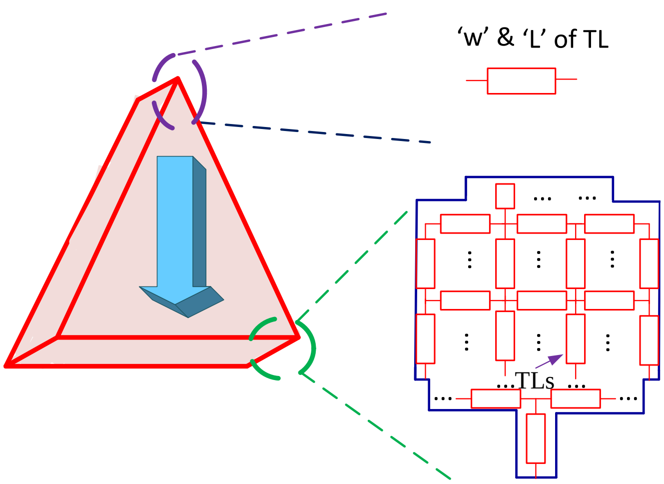

Fig. 1. General perspective of the BUO method for configuring the microstrip antenna in the ADS.

Typically, when the microstrip antenna is bended, the EM-simulations are lasting longer, because of the usually increased number of unknowns to achieve the same accuracy as for the planar case. This first phase of the methodology is essential in designing, as any designer can extract the general configuration of the microstrip antenna before bending. If the achieved outcomes are appropriate in terms of S_{11}, and RPs, then the designer confidently can proceed to the next step, i.e., bending the antenna.

B. Bending the configured antenna in the CST environment and generating the layout

After configuring the microstrip antenna using the BUO method in the ADS environment and considering the achieved initial outcomes of the antenna characteristics, the overall geometry, incorporating the ground plane, dielectric and radiator, is bended around a given axis in the CST environment. This environs is reliable for bending operation; conformal geometries can be required, for example in wearable devices as wearable or implanted devices. As a point, the overall antenna can be bended using the '*Bend Shape function*' of the CST Suite. Such operation will alter the antenna performances; hence, the geometry and feeding point location should be fine-tuned. In particular, here the final location of the feeding point is determined using the replacement optimization where the feeding point is moving within the bended surface up to achieving the targeted output results.

III. Simulation Results

This section devotes to firstly present the achieved initial configuration of the microstrip antenna using the BUO method. Then the actual design of bended antenna with the simulation results are shown, briefly.

The main step for initializing the optimization is to define the substrate. Here, Rogers (RO4003C) with the specifications of $\tan\alpha$= 0.0027, ε_r= 3.55 and thickness of 1.52 mm. has been used. Afterwards, the BUO algorithm is employed for configuring the structure of microstrip antenna. Figure 2 presents the general structure of the microstrip antenna that is constructed using the BUO method in the Keysight ADS tool. In this procedure, the number of TLs are sequentially increased and also by using the random iteration optimization, the values for the various 'w' and 'L' parameters are determined. Table I presents various design parameters with values of the optimized microstrip antenna.

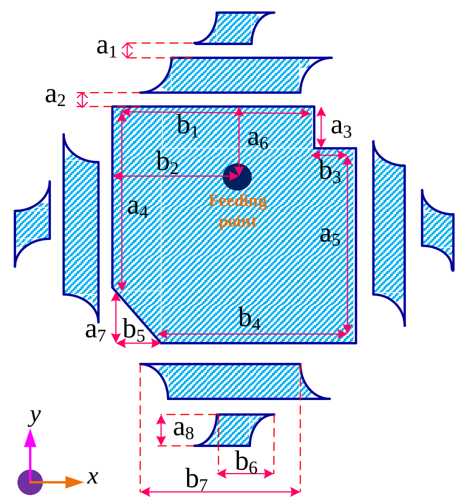

Fig. 2. Optimized microstrip antenna using the BUO method (width and length are in mm; drawing not in scale).

TABLE I
Values of constructed TLs for the antenna in Fig.2

width	value (mm)	length	value (mm)
a_1	1.0	b_1	7.0
a_2	1.0	b_2	3.2
a_3	0.6	b_3	0.6
a_4	5.8	b_4	5.8
a_5	7.0	b_5	1.8
a_6	3.0	b_6	1.9
a_7	1.8	b_7	5.0
a_8	1.96	-	-

The configured flat antenna consists of one main patch in the center that is surrounded by the passive resonators where the antenna is fed by a coaxial cable. The antenna is mounted on the ground plane with the extension of 19 mm and 17 mm, along x and y directions, respectively. After configuring the antenna in the ADS environment, the related layout is extracted and imported into the CST environment.

As described above, in order to use microstrip antennas in the future wearable devices, the antennas must be bended. For this case, the configured microstrip antenna is bended in the CST environment with a 45° curvature around an axis at a distance of 1.52 mm from the ground plane (in the opposite to the radiator direction). Figure 3 presents the general structure of the bended antenna in the CST environment.

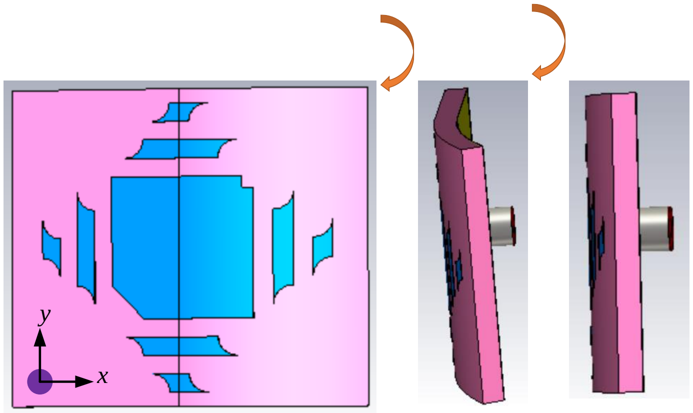

Fig. 3. Illustration of the bended microstrip antenna with the rotated figures to show clearly the total shape that is modelled in the CST environment.

Figure 4 presents the S_{11} performance of the microstrip antenna before and after bending. We firstly design the microstrip antenna in the ADS environment that simulation result reveals that the bandwidth of this flat antenna is from 9.0 GHz to 9.6 GHz. Afterwards, the layout of this flat antenna is transferred to the CST environment and then it is bended. The simulation result shows that there is around 200 MHZ shifting in the resonant frequency due to the difference in matching. The overall bandwidth of the bended antenna is from 8.8 GHz to 9.4 GHz. The RPs of the bended antenna in the H-plane for various frequencies of 8.8 GHz, 9.1 GHz, and 9.4 GHz are also depicted in Fig. 5.

The total simulation last around 50 minutes in the practical CPU execution environment includes 11th Gen Intel(R) Core(TM) i7-1165G7 CPU @ 2.80 GHz with 16.0 GB RAM. The major part of this 50 min is represented by the CST simulation, since the TL simulation in ADS last only 20 min.

IV. Conclusion

The EM-simulation is typically time consuming in the case of conformal antennas that are used, for example, in wearable devices. This paper presents a new method for designing bended microstrip antennas where the post-layout can be generated with reduced effort. For this case, firstly the configuration of microstrip is generated using the BUO method in the ADS environment by sequentially increasuing the number of TLs. Then, the generated antenna is transferred

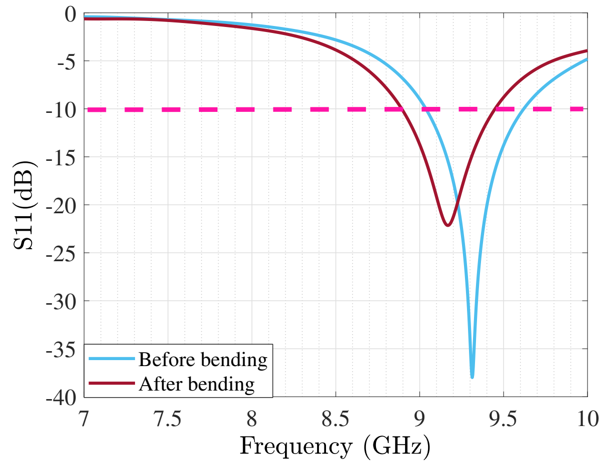

Fig. 4. S_{11} performance of microstrip antenna before and after bending.

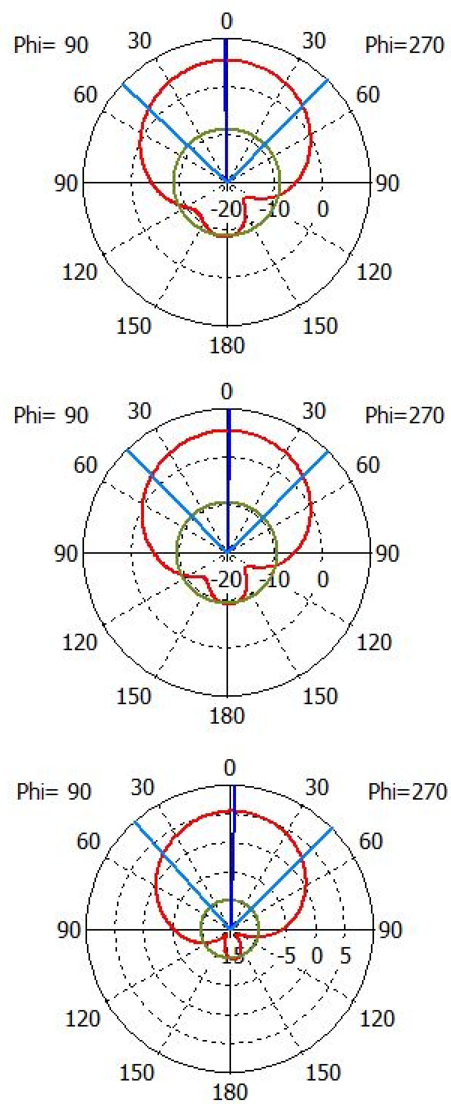

Fig. 5. Radiation pattern of the bended microstrip antenna in the H-plane at 8.8 GHz (top) 9.1 GHz (middle), and 9.4 GHz (bottom).

into the CST environment and bended there. In summary, two EDA tools as ADS and CST are performed sequentially for configuring the flat microstrip antenna and then bending it, respectively. This methodology provides ready-to-fabricate layout more easier as the initial configuration is generated using the BUO method.

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