Multiband Antenna for RF Energy Harvesting

Ngan Nguyen[1], Ninh Nguyen Tuan[1], Quoc Cuong Nguyen[1], Vu Bang Giang Truong[2], Monai Krairiksh[3], Minh Thuy Le[1]
[1]School of Electrical Engineering, Hanoi University of Science and Technology, Vietnam
[2]Vietnam National University, Vietnam
[3]King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.
Email: thuy.leminh@hust.edu.vn

***Abstract* - This paper presents a multi resonant bow-tie slot antenna for Rectifying Antenna in Ambient RF Energy Harvesting (RFEH). The proposed antenna operates at five frequencies 0.9 GHz, 1.8 GHz, 2.1 GHz, 2.45 GHz and 5.8 GHz corresponding with ambient RF sources in our environment by changing the position and size of the air gap on the traditional bow-tie antenna as well as bow-tie antenna. A good agreement is observed between the simulation and measurement results. The proposed antenna is suitable for high efficiency RF energy harvesting system.**

***Index Terms* —Slotted bow-tie antennas, GSM, LTE, Rectifying antenna, RF energy harvesting, Co-planar strip lines**

1. Introduction

Nowadays, with the development of wireless communication technologies, the design of mobile devices and wireless sensor network nodes have been attracting almost companies and laboratories. The compact and low power consumption as well as autonomous energy are emergency requirement for design of these devices. Currently, wireless sensor nodes are powered by batteries. Therefore, its lifetime is limited even these sensor nodes are very low power, it requires periodic battery replacement. One of the solutions is to design a circuit that converts the available power sources in the environment, converting them into direct-current charging or directly powering the device. Therefore, Wireless power transfer (WPT) and RF energy harvesting (RFEH) have attracted significant attention in the past few years [1][2][3][4]. A rectifying antenna (rectenna) is one of the most popular devices for WPT and RFEH applications, several works have been made [4][5][6]. As RF sources in the environment are from UHF to Microwave frequency including 0.9 GHz (GSM-900, RFID), 1.8 GHz (GSM-1800), 2.1 GHz (UMTS, LTE), 2.45 GHz (Wi-Fi, Zigbee, Bluetooth), 5.8 GHz (Wi-Fi, DSRC), multiband and broadband rectennas are promising solution to harvest RF power from different sources and from different channels simultaneously to DC power. Thus, they give the higher efficiency and total output power than conventional rectenna at single frequency. Antenna plays an important component in rectenna, it must operate in all available frequency bands in the surrounding environment to harvest the most energy in order to have highest performance rectenna.

In this work, a multiband bow-tie slot antenna is proposed and designed for RFEH application. A traditional bowtie antenna is made from a bi-triangular sheet of metal with the feed at its vertex. This type of antenna is used extensively in many applications such as ground penetrating radar and mobile station [7][8][9]. Comparison between bowtie and the fractal antennas showed that the bow-tie antenna has a wider bandwidth, higher gain, lower font to back ratio, lower cross polarization level and its dimension is smaller [10]. In [7], performance improvement is achieved by using antenna with rounded patches instead of using conventional flat-ended ones. The design of a bowtie antenna fed by broadside-coupled strip lines for the 2.4 GHz ISM band is described. The two fins of the bowtie are on the two sides of the substrate. A quarter wave transformer is used to transform the micro strip line input to the BCS (broadside-coupled strip lines) feed. In [11], this antenna is designed for the mobile station antenna at the 2.4 GHz ISM band. A wideband coplanar waveguide-to-coplanar strips (CPW-to-CPS) balun is used to transform the unbalanced CPW feed line to a balanced CPS feed line for the dipole antenna. However, its structure is quite cumbersome.

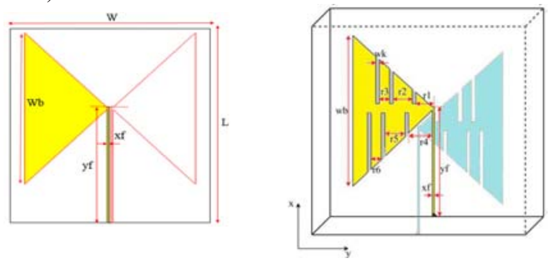
A multi-band bowtie slotted antenna for RFEH applications is designed in this paper. The slotted antenna is selected to obtain an omnidirectional radiation patter so that the antenna harvests the most electromagnetic waves that available in the environment. In this research, numbers of slits are inserted on each arm of the bowtie antenna, leading to desired resonances. The CPS (Coplanar strip lines) feeding technique is selected for achieving a good impedance matching. By controlling the location and size of the slits, operating frequencies are at 0.9 GHz, 1.8 GHz, 2.1 GHz, 2.45 GHz and 5.8 GHz as desired.

2. Multiband bow-tie antenna design

In this section, slotted antenna design with different numbers of slits with different dimensions are presented. Antenna is designed on the Rogers 4003C substrate with a dielectric constant of 3.55 and a height of 0.8 mm. The CPS (Co-Planar strip lines) feeding technique is selected to have a good impedance matching. Length of CPS is taken as 90 mm and width as 0.75 mm with spacing between lines as 1 mm. CPS-fed bow tie with 90° extended angle results in the widest bandwidth. The two fins of the bow tie are on the two sides of the substrate, respectively. A simple slotted bowtie antenna is shown in Fig.1. In a first design, the dimensions of this antenna are calculated for resonance at 0.9 GHz.

In a second step of design, four slits were inserted on each arm of the bowtie. They all have width of 3 mm and length of slits depends on the position. The S11 of this configuration is shown in Fig. 2. It shows that the effect of the slits results in a second resonant frequency at 2.45 GHz. By changing the dimensions as well as position of the slits, the resonant frequency is shifted to desired frequency.

To obtain five bands (at 0.9 GHz, 1.8 GHz, 2.1 GHz, 2.45 GHz and 5.8 GHz), two splits are added on each arm of the bowtie combined with the changing position of these slits. The geometry and parameters of five bands antenna are shown in Fig. 1b and Table I. The S11 coefficient of this antenna is shown in Fig. 2 showing that five desired bands are obtained. Otherwise, this antenna resonances at 1.7 GHz (for 3G) and 3.4 GHz as well as 4.2 GHz for future 5G.



a) b)

Fig. 1. a) Initial bow-tie antenna; b) Multi- band bow tie antenna

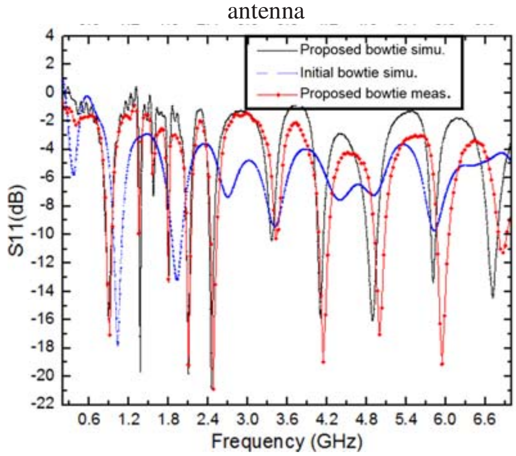


Fig. 2. S11 coefficients of Bow-tie antenna

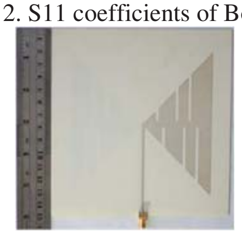


Fig. 3. The prototype of multi-band bow-tie antenna

TABLE I: Parameters of multi-band Bow-tie antenna

Parameters	Value (mm)	Parameters	Value (mm)
L	150	x	1.75
W	150	y_f	90
W_b	120	d	1
r_1	2	r_6	3
r_2	9.1	w_k	3
r_3	4	W_b	115
r_4	14.5	X_s	150
r_5	6	Y_s	150

3. Discussion and Conclusion

The procedure of design multi band antenna is presented in this paper. The desired frequencies are achieved by inserting and changing position of slits in two arms of bow tie antenna. The proposed antenna is working at five frequencies corresponding with RF sources that available in environment for RF energy harvesting system.

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