On the Effectiveness of a Z element for Enhancement of Matching, Gain and Reactive Near Fields of a Small Antenna

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On the Effectiveness of a Z element for Enhancement of the Matching, Gain and the Reactive Near Fields of a Small Antenna

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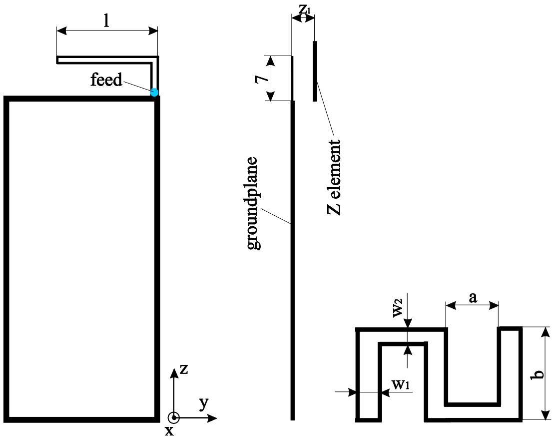
Abstract

In this paper, an electrically small antenna with a parasitic Z-shaped element is presented. Compared to the previously proposed design, it has been proved that even if the Z element is disconnected from the ground plane, it still works as a natural matching network for the antenna. Two designs for two different frequency bands have been presented. The natural matching property has been demonstrated for an antenna working at 5.11 GHz and then another design tuned to 2.45 GHz has been investigated. The gain and the **R**eactive **N**ear **F**ields (RNF) of the second design is studied, showing a high decrease of the radiation toward the hand. Moreover, for the antenna with the Z element, the reduction in the magnetic RNF at distance 15 mm is almost 2 dB A/m compared to the antenna itself.

1. Introduction

In the last decade, the metamaterials have attracted interest and extensive research has been conducted in order to find good solutions for the enhancement of antenna's properties [1]-[3]. Recently in [4], the proposed a metamaterial-inspired Z antenna is easy-to-build, more efficient and naturally matched to 50 ohms source antennas. The main innovation of this structure is the introduction of a parasitic Z-shaped element in the RNF of the radiator and connected to a ground plane. The natural matching and the high overall efficiency have been demonstrated and experimentally verified at UHF frequencies [5]. The RNF in free space are highly changeable and can vary significantly in two very close points in the space [6], [7]. Inspired by the proposed Z antenna, in this paper, a new design fitting into a candy bar phone with typical dimensions of 40 x 100 x 10 mm will be presented. In that structure the parasitic element is not connected to the ground plane. The simulations have been done with the parallel **F**inite **D**ifference **T**ime **D**omain (FDTD) developed at the Antennas, Propagation and Radio Networking group at Aalborg University.

2. Inspired-Z-antenna Design



a) b)

Fig. 1 Inverted L Antenna (a) and a new structure with the Z element (b)

The geometry of the proposed structure is shown in Fig. 1 along with definition of its dimensions. The parasitic Z-shaped element is simplified since there is no lumped element on it. Two designs are proposed, one for each resonance frequency. The first one is showing the matching property at 5.11GHz.

In the second design, it has been tuned - by cutting the antenna - to a more usable frequency of 2.45GHz. The values w_1=3 mm and w_2=2 mm are common in both designs. The design parameters unique to each design are summarized in Table 1.

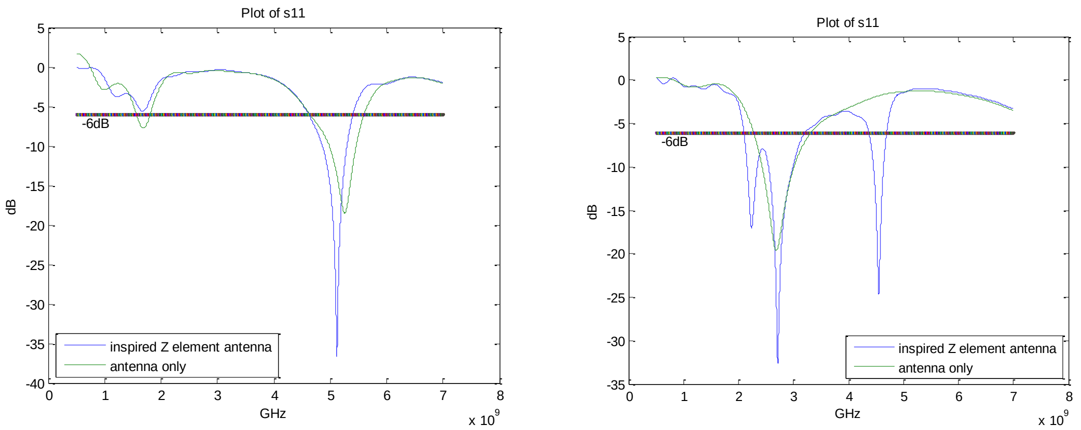
Table 1 : Design dimensions for each frequency

Resonating frequency	Z element dimensions		Antenna dimensions	Distance Z-Antenna
	a	**b**	**l**	**Z1**
5.11 GHz	9	10	40	5
2.45 GHz	15	10	21	2

In both cases the Z element is centered in y=0 and the dimensions have been chosen to have the best matching.

3. Numerical Results

In Fig. 2, the simulated s11 values show big enhancement in the matching when the Z element is added close to the monopole.



(a) (b)

Fig. 2 s11 of the ILA compared with the Z element-antenna structure for the 5GHz design (a) and the 2.45 GHz design (b).

In the 5 GHz design, adding the Z element improves the matching from -18dB to -36dB. Also it decreases the resonance frequency from 5.28GHz to 5.11GHz. The -6dB bandwidth is reduced when the parasitic element is added from 997MHz to 739MHz. In the 2.45GHz design, adding the Z element is improving the matching from -19dB to -32dB. The main resonance frequency does not change but two more appear at 2.23GHz and 4.54GHz. The -6dB bandwidth is increased when the parasitic element is added from 1000MHz to 1130MHz. The gain of the antenna without and with the Z element at 2.45GHz design is plotted in Fig. 3.

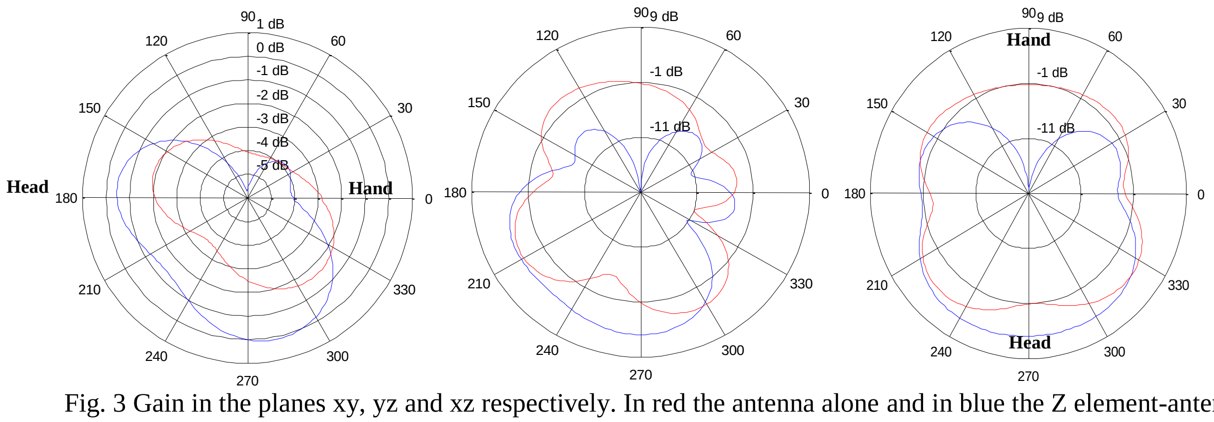


Fig. 3 Gain in the planes xy, yz and xz respectively. In red the antenna alone and in blue the Z element-antenna structure. The Head-Hand direction is shown in the concerned figures.

From the gain in the xy plane, it can be seen that the gain is shifted up to 1.5dB in the direction hand to the head. In the yz and xz planes, the gain has a minimum at θ=90 ˚ meaning that the power radiated toward the hand has been highly reduced for the antenna with the Z element compared to the ILA itself. The RNF are shown in Fig. 4.

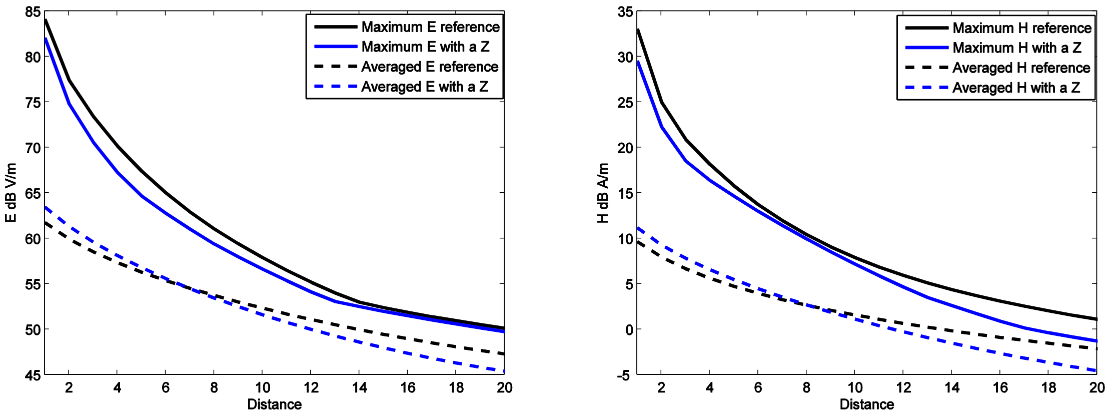


Fig. 4 E and H RNF for the 2.45GHz resonating antenna

The RNF are interested in reducing the interaction between the mobile phone and the hearing aids (complying with the **H**earing **A**ids **C**ompatibility (HAC) of the mobile phones) and the interaction of the antenna with the user. Concerning the HAC, the maximum E and H values are of interest. The highest reduction in the maximum E is at distance 5 mm from the antenna, and it is close to 2.2 dB V/m. A significant improvement of 2 dB A/m in the maximum and averaged H value has been obtained at distance 15 mm.

4. Conclusion

A new antenna design has been presented. This structure is composed by a ILA resonating at a certain frequency and a parasitic Z-shaped element placed in the RNF of the radiator. It has been observed that the Z element, disconnected from the ground plane, introduces a very good match for a 50 ohms source (-35 dB), improves the gain of the resulting antenna, enhancing in the gain up to 7dB in the head-hand plane, and reduces the E and H RNF. The future goal is to design, fabricate and experimentally test antennas for the GSM and LTE standards having reduced RNF and improved directivity and interaction with the user as well.

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