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A NEW INNOVATIVE ANTENNA CONCEPT FOR BOTH NARROW BAND AND UWB APPLICATIONS

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Abstract—In this paper, we propose a new antenna structure that can be adjusted for narrow band as well as UWB applications. The proposed antenna is of very simple geometry and easy to manufacture. It is monopole type antenna and made of copper. We present antennas with the same geometrical concept and different dimensions. Antenna designed for narrow band operation exhibits 3.7% bandwidth at 800 MHz frequency ($S_{11} < -10$ dB). Two UWB antenna designs exhibit 77% bandwidth (from 2 to 4.5 GHz) and 54% bandwidth (from 2.6 to 4.5 GHz) and are of smaller size compared to the dielectric resonator antennas (DRA). Furthermore, it can be easily shown that using the proposed geometry broad family of antennas (for operation in various frequency bands) can be designed.

1. INTRODUCTION

Antennas are characterized with many parameters such as frequency range of operation, far field radiation pattern, directivity, gain, efficiency, size, etc.. An important parameter is operational bandwidth which is defined as a frequency range at which antenna has VSWR less than a chosen value, for example 2 ($S_{11} < -10$ dB). Regarding to that, antennas can be classified as narrow band and broad band or ultra wide band (UWB) antennas.

Narrow band antennas are antennas designed for operation at specific frequency. Common narrow band antenna designs are dish antennas, dipole, loop, microstrip patch or Yagi-Uda antenna [1–4].

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Some application fields for narrow band antennas are in astronomy, cognitive radio, medical devices (MRI imaging).

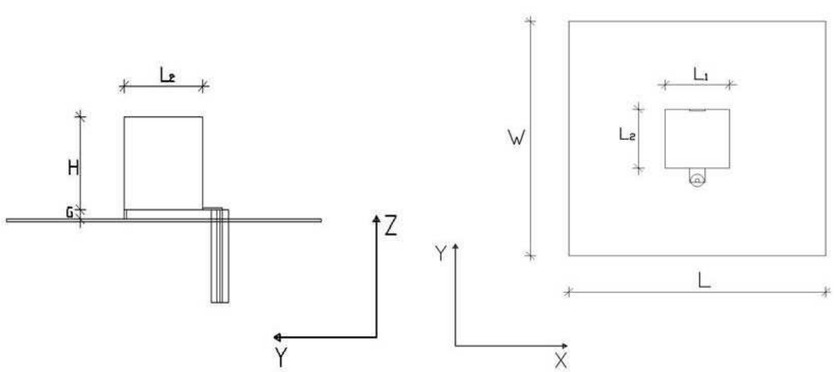
An antenna is considered to be UWB antenna if its operational bandwidth exceeds 500 MHz or 20% of the center frequency. Depending on application, there are different demands for UWB antennas, such as low profile, maintained radiation pattern over the entire operational bandwidth, etc.. Some examples of UWB antenna models are in [5–11].

In this paper, we present antenna geometry that exhibits UWB or narrow band characteristics depending on the load position. Paper is organized as follows. Section 2 describes the basic antenna geometry, Sections 3 and 4 show simulated and measured results for the narrow band and UWB antenna designs, while Section 5 gives comparison of the proposed designs with some existing solutions.

2. ANTENNA GEOMETRY

This antenna geometry is presented for the first time in [12]. In that abstract, the proposed antenna geometry is optimized for UWB operation with $S_{11} < -10\,\text{dB}$ from 1.8 to 15 GHz. The height of the antenna was 0.12λ calculated at the lowest operational frequency.

The proposed antenna is a monopole type, mounted on the ground plane with coax probe feed. All antenna parts are made of 0.3 mm thick copper. Figure 1 shows its geometry. The antenna consists of an empty rectangular box that has five sides. The box is placed above ground plane on the piece of foam (to provide stability). The open side of the box is faced toward ground plane, with the top side parallel to the ground plane. The coax probe feed is connected to the small

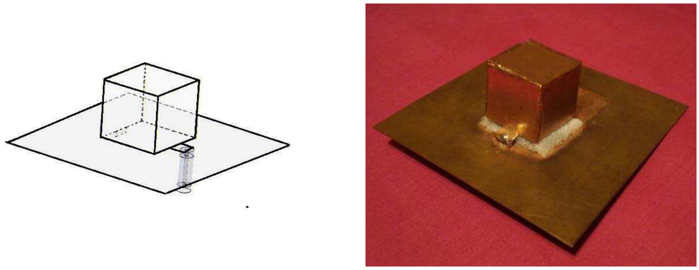


(a) (b)

Figure 1. Antenna geometry — side and top view.

rectangular portion of the antenna (parallel to the ground plane) which starts from the mid point on the front side of the box. The ground connections are made with copper strap (inductive load) via a small rectangular extensions which start from the mid point of the each box side except one where is feed point of antenna.

The antenna parameters (Figure 1) are: L and W, representing ground plane size, L_1, L_2 and H, representing box length, width and height, and G, representing distance from the ground plane to the box. Figure 2 shows axonometry views of the geometry.



(a) (b)

Figure 2. Axonometric view of the proposed geometry (a) and fabricated prototype (b).

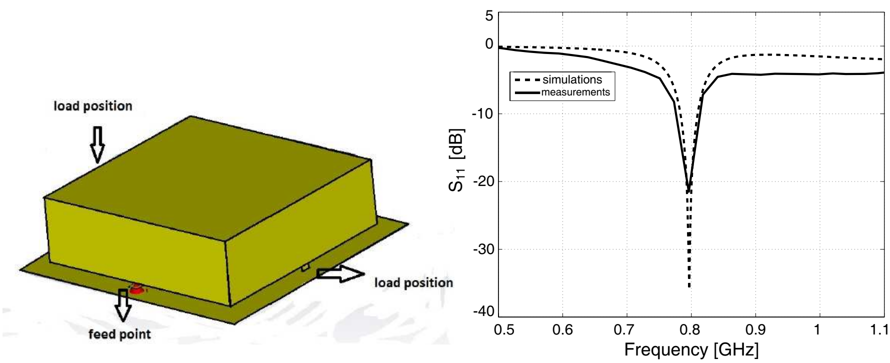
3. NARROW BAND ANTENNA DESIGN

Both narrow band and UWB antenna design optimizations are performed with CST Microwave Studio software. Reflection coefficients and radiation patterns are also simulated by using the same software. Fabricated antenna optimized for narrow band operation has following dimensions: $L = 120\,\text{mm}$, $W = 120\,\text{mm}$, $L_1 = 100\,\text{mm}$, $L_2 = 100\,\text{mm}$ and $H = 30\,\text{mm}$. In narrow band as well as UWB designs, the height of the box above ground plane is the same and is equal to $G = 2\,\text{mm}$. All short straps (that connect box and ground plane) and feeding rectangles are of the same size, 5 by 5 mm.

In narrow band design there were two loads. If the box side where the feed point is placed is 'front' side, then loads are placed to the box sides next to the 'front' side. Figure 3(a) displays axonometric view of the narrow band design while in Figure 3(b) simulated and measured reflection parameters are shown. Fabricated antenna exhibits 3.7% bandwidth at 800 MHz center frequency. In terms of λ at 800 MHz, antenna dimensions are as follows: ground plane dimensions are $0.32 \times 0.32\lambda$ and box size is $0.27 \times 0.27 \times 0.085\lambda$.

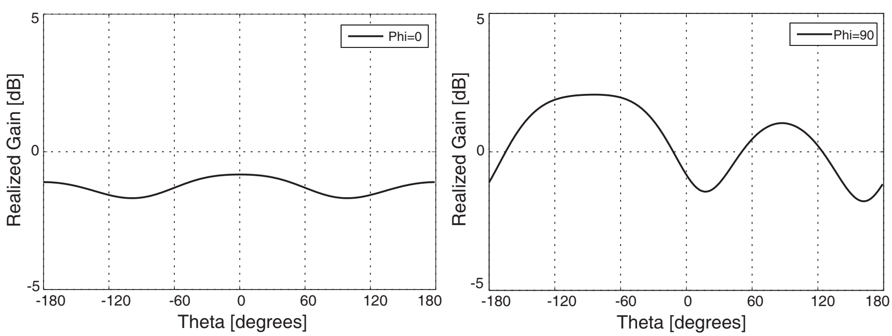
Simulated radiation patterns of the narrow band antenna design are presented in Figures 4, 5 and 6. This antenna exhibits broad-beamwidth radiation pattern. Ripples observed in E and H plane are small, in the range of 2 dB.

An interesting observation is related to the loads position. In fabricated example, both loads that connect box with ground plane start from the mid point of the box side. Figure 7 shows changing in the operational frequency caused by changing of the load positions (in presented simulations loads start ±5 mm away from the mid point of the box side). This property can be used for the fine tuning of antenna's operational frequency.



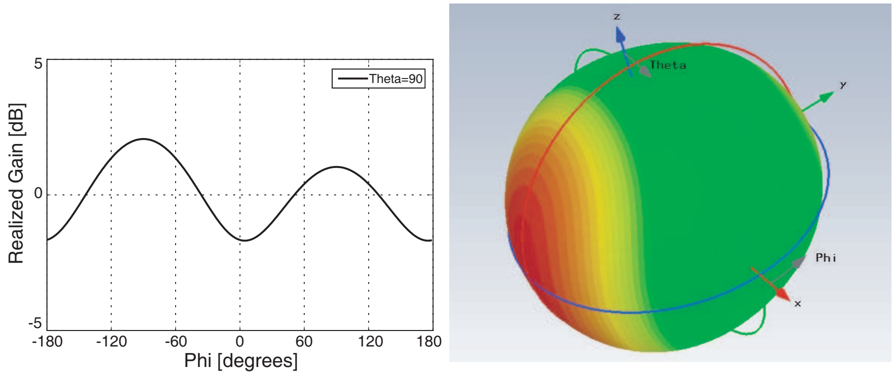
(a) (b)

Figure 3. Axonometric view of the narrow band antenna (a) and simulated and measured S_{11} (b).



(a) (b)

Figure 4. Simulated radiation pattern at 800 MHz frequency for (a) $\varphi = 0$ and (b) $\varphi = 90$.



(a) (b)

Figure 5. Simulated radiation pattern at 800 MHz for (a) $\theta = 90$ and (b) in 3D.

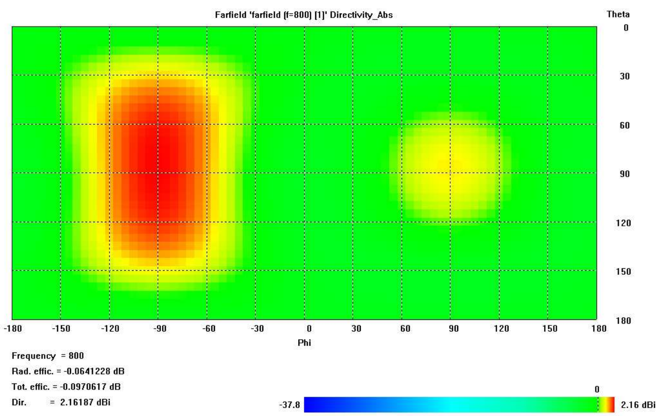


Figure 6. Simulated radiation pattern at 800 MHz.

4. UWB ANTENNA DESIGN

Using the same concept, the two antennas designed for UWB operation are fabricated. The antenna 1 has following dimensions: ground plane dimensions are $L = 60$ mm and $W = 60$ mm, box dimensions are $L_1 = 20$ mm, $L_2 = 20$ mm and $H = 20$ mm. In this design, there is only one load which is placed on the side oposite the front side where feed rectangle is placed. Figure 8 displays (a) axonometric view and (b) simulated and measured reflection coefficients of UWB antenna 1. Our measurements were constrained by the maximum operation frequency of VNA, which is 4.5 GHz. Designed antenna exhibits 77% bandwidth from 2 to 4.5 GHz. Its electrical height is 0.15λ, calculated at the lowest operational frequency.

The second antenna, antenna 2, has the following dimensions: ground plane dimensions are $L = 80$ mm and $W = 80$ mm, box dimensions are $L_1 = 20$ mm, $L_2 = 5$ mm and $H = 10$ mm. Figure 9 shows simulated and measured reflection coefficient of the antenna 2. Antenna 2 exhibits 54% bandwidth from 2.6 to 4.5 GHz. Its electrical height is 0.1λ, calculated at the lowest operational frequency.

Simulated radiation pattern of fabricated antenna 1 is presented

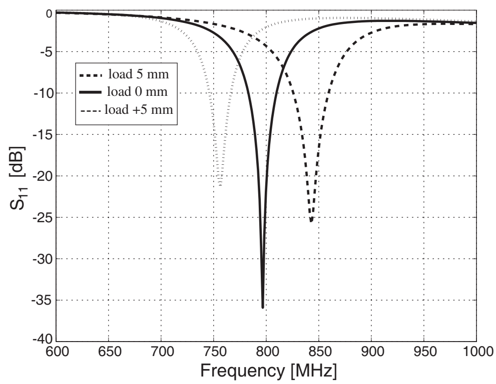


Figure 7. Simulated S_{11} for the three different load positions, 5 mm left and right from the nominal (center of the box side) load position.

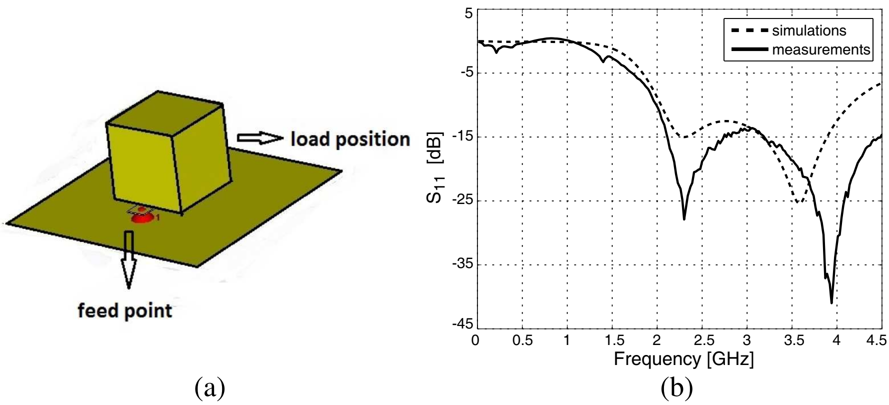
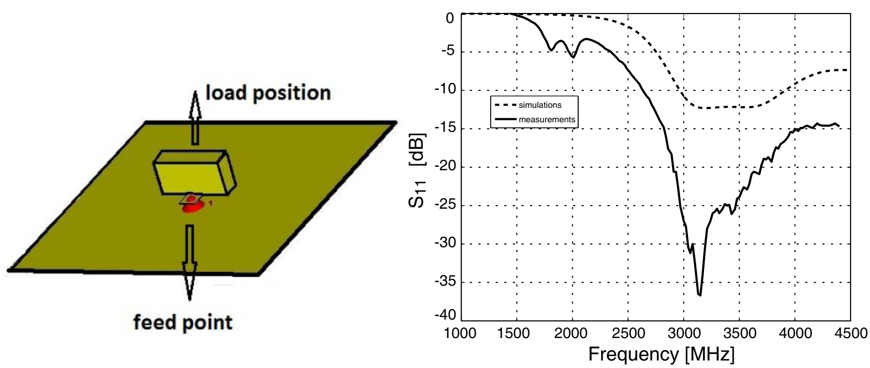


Figure 8. Fabricated antenna 1, axonometric view (a) and simulated and measured S_{11} (b).

in Figures 10, 11 and 12. Simulations are performed at 2.2 GHz frequency. From the presented simulations is seen that antenna 1 exhibits monopole-like radiation characteristics.

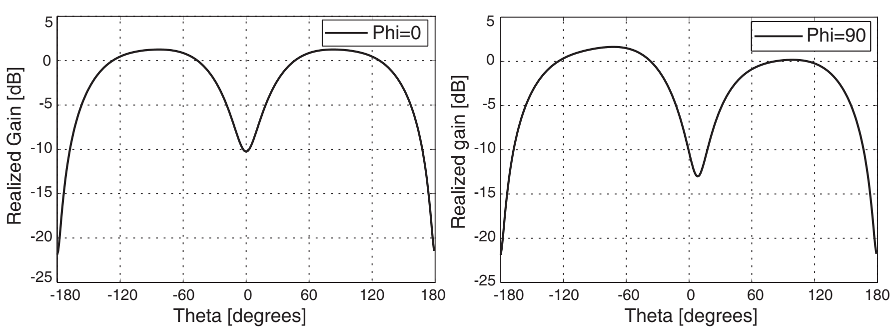
5. THE COMPARISON AND ADVANTAGES

The presented geometry is very simple and convenient for re-scaling for operation at desired frequency or frequency range. Because of its dimensions in terms of λ, narrow band design is suitable candidate for RF transmit antenna for high field MRI imaging (7 Tesla and higher), instead of big patch antennas [13]. Another advantage of the proposed antenna, besides its size, is the tuning mechanism — it is possible



(a) (b)

Figure 9. Fabricated antenna 2, axonometry view (a) and simulated and measured S_{11} (b).



(a) (b)

Figure 10. Simulated radiation pattern of UWB antenna 1 at 2.2 GHz frequency for (a) $\varphi = 0$ and (b) $\varphi = 90$.

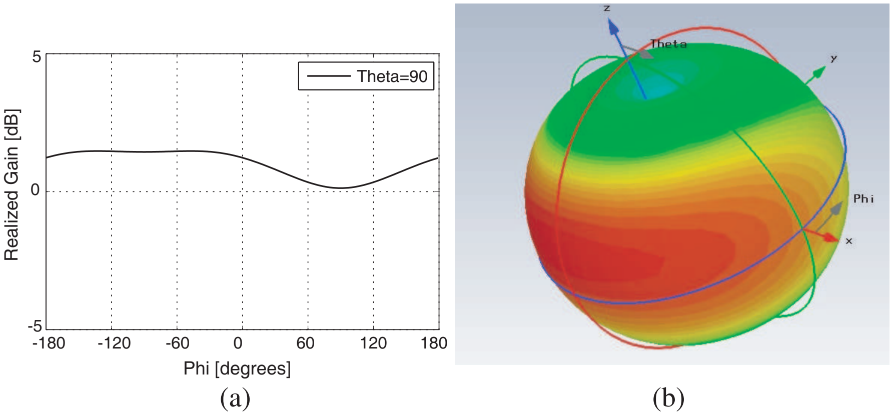


Figure 11. Simulated radiation pattern of UWB antenna 1 at 2.2 GHz for (a) $\theta = 90$ and (b) in 3D.

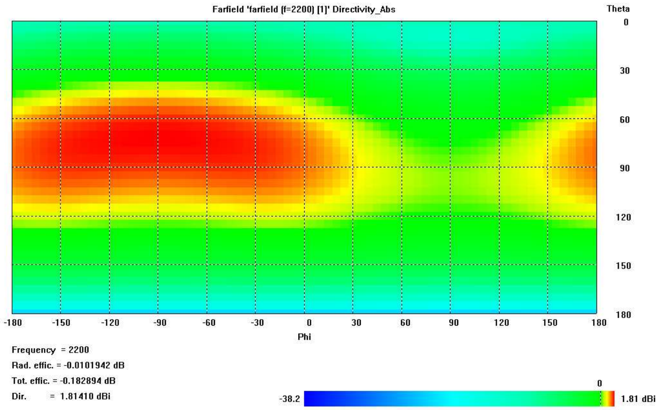


Figure 12. Simulated radiation pattern of UWB antenna 1 at 2.2 GHz.

to fine tune antenna's operation frequency by changing load position, without introduction the lumped elements (capacitors or inductors).

The above presented UWB antenna designs are compared with monopole type antennas [14, 15], as well as with small dielectric resonator antennas DRA [16–19]. In [17], proposed DRA design has a height of 0.268λ and exhibits 26.8% bandwidth (from 3.04 to 3.98 GHz). Antenna proposed in [18] exhibits 35% bandwidth (from 2.8 to 3.9 GHz) and its height is approximately 0.2λ. Our UWB designs exhibit the following parameters: fabricated antenna 1 has height of

0.15λ and its operational bandwidth ($S_{11} < -10\,\mathrm{dB}$) is 77% from 2 to 4.5 GHz. The height of the fabricated antenna 2 is 0.1λ and operational bandwidth is 54% from 2.6 to 4.5 GHz. In each case, designed antennas exhibit wider operational bandwidth and smaller electrical size (calculated at the lowest operational frequency).

A big advantage of the proposed geometry over DRA designs is in the simplicity and no need for using of dielectric materials.

6. CONCLUSIONS

We proposed a simple antenna geometry that can be optimized for both narrow band and UWB operation. The antenna is made of copper with coaxial probe feed. Its main parameters, such as ground plane size, box dimensions and load positions, determine the antenna's characteristics and could be adjusted for different frequencies or frequency ranges. We showed that the antenna will have narrow band characteristics if loads are placed in the middle of the two box faces (left and right from the side where feed rectangle is placed). On the other hand, antenna exhibits UWB characteristics if design has load only on the side opposite from the feed point side. Finally, this antenna is convenient to match 50Ohm due to monopole type feeding. Thus, the presented results may be useful in developing antennas for broad range of applications.

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