Arrangements and Applications of Self-grounded Antennas

http://dx.doi.org/10.1109/EuCAP.2014.6901697

Arrangements and Applications of Self-grounded Antennas

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***Abstract*—The self-grounded antenna is a new type of compact ultra-wideband antennas with simple geometries. One of the characteristics of this type antenna is its high flexibility: the configuration of the antenna can be arranged in many different ways for different applications. In this paper, we overview the typical arrangements of the self-grounded antennas, and their performance for different applications.**

***Index Terms*—Self-grounded antenna, ultra-wideband, MIMO antenna**

I. Introduction

There is an increasing demand of ultra-wideband antennas in wireless communication devices (allow communication in several frequency bands) and other systems (sensing systems, tracking and positioning system, medical monitoring, etc.). The use of wideband signals is associated with many positive aspects and advantages as, for example, described in [1].

Different UWB antennas are required for different UWB applications. Many UWB antennas have been developed [2]–[5]. We presented a new type of UWB antennas - the self-grounded antennas in the paper [6]–[9]. One of the characteristics of this type antenna is its high flexibility: the configuration of the antenna can be arranged in many different ways. Several arrangements of the basic geometry of self-grounded antenna and their applications are overviewed below.

II. Model of Working Principle

We can use one halfwave tilted V-form electric dipole and two halfwave magnetic dipoles, as shown in Fig. 1, to model the self-grounded Bow-Tie antenna for the radiation performance. The electric dipole represents the radiating electric current on the Bow-Tie surface, and the two magnetic dipoles represent the loop electric current caused by the self-grounding. The electric dipole can be written as

$$\mathbf{J} = \begin{cases} I_0 j(l')\hat{\boldsymbol{l}}_1, & -\frac{l_e}{2} < l' < 0 \\ I_0 j(l')\hat{\boldsymbol{l}}_2, & 0 < l' < \frac{l_e}{2} \end{cases} \quad (1)$$

where

$$j(l') = \frac{sin[k(l_e/2 - l')]}{sin(kl_e/2)}$$

and $k = 2\pi/\lambda$ is the wave number. The tilted angle α for the dipole in the modeling is the same as the tilted angle of the arms in the real antenna.

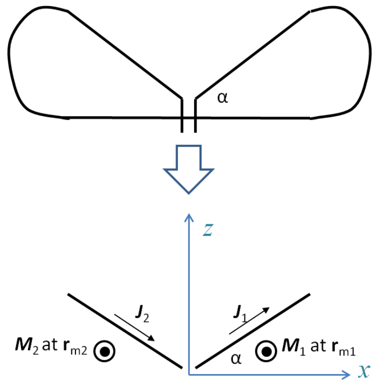

Fig. 1. Modeling of a self-grounded Bow-Tie antenna by a Huygens' source: a halfwave electric dipole and two halfwave magnetic dipoles.

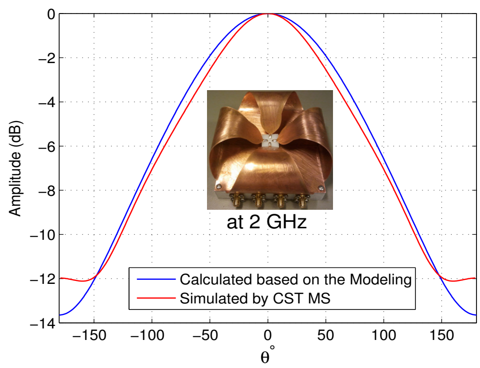

Fig. 2. Radiation pattern in $\varphi = 0$ plane of a 1.5–3GHz dual-polarized self-grounded Bow-Tie antenna: calculated based on the modeling and simulated by CST MS.

The magnetic dipoles can be written as

$$\mathbf{M} = \begin{cases} M_0 m(y')\hat{\mathbf{y}}, & -\frac{l_m}{2} < y' < 0 \\ M_0 m(y')\hat{\mathbf{y}}, & 0 < y' < \frac{l_m}{2} \end{cases} \quad (2)$$

where $M_0 = \eta I_0$ ($\eta = 377$ ohms, free space impedance),

$$m(y') = \frac{sin[k(l_m/2 - y')]}{sin(kl_m/2)}$$

and the locations of r_{m1} and r_{m2} are defined as

$$r_{m1} = (l_e cos\alpha/2, 0, l_e sin\alpha/4)$$
$$r_{m2} = (-l_e cos\alpha/2, 0, l_e sin\alpha/4)$$

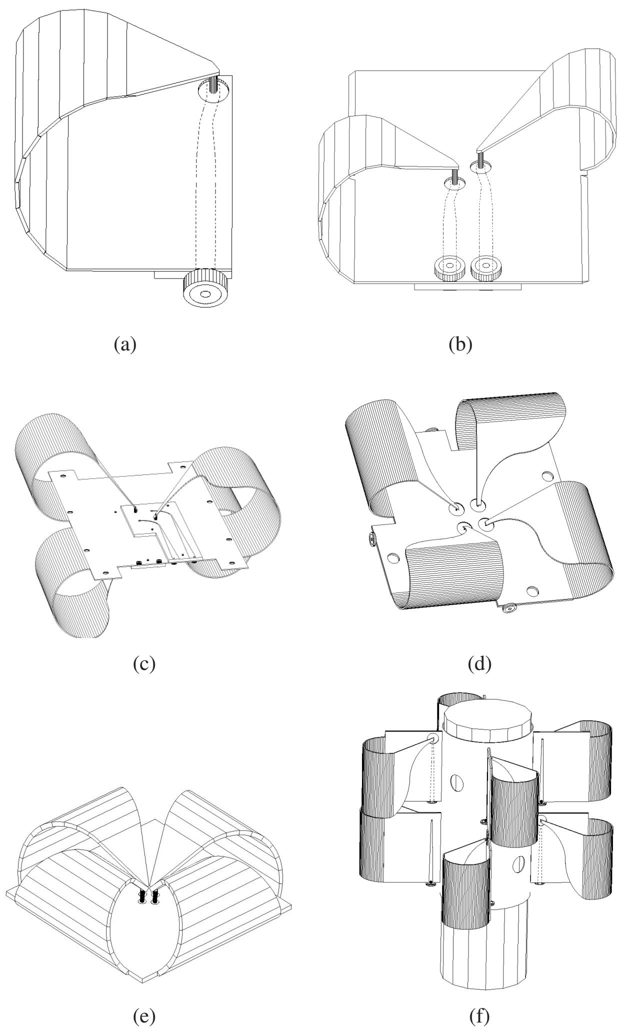

Fig. 3. The self-grounded antenna and different arrangements: (a) basic geometry; (b) two-branch; (c) four-branch double-sided; (d) four-branch one-sided; (e) dual-polarized; (f) eight-branch poster-mounted.

Fig. 2 shows the calculated radiation pattern based on the above model for a 1.5-3GHz self-grounded Bow-tie antenna at 2 GHz [10], and the simulated one by using CST MS. It can be seen that the agreement is very good.

III. Arrangements

The basic geometry of the self-grounded antenna is shown in Fig. 3(a). Then, we can arrange the basic geometry in different ways: two-branch self-grounded antenna (Fig. 3(b)), four-branch double-sided self-grounded antenna (Fig. 3(c)), four-branch one-sided self-grounded antenna (Fig. 8(d)), dual-polarized directional self-grounded antenna (Figs. 8(d) and 3(e)), eight-branch poster-mounted self-grounded antenna (Fig. 3(f)), etc.

IV. Performance

In this section, we will illustrate different performance of different arrangements of the self-grounded antenna.

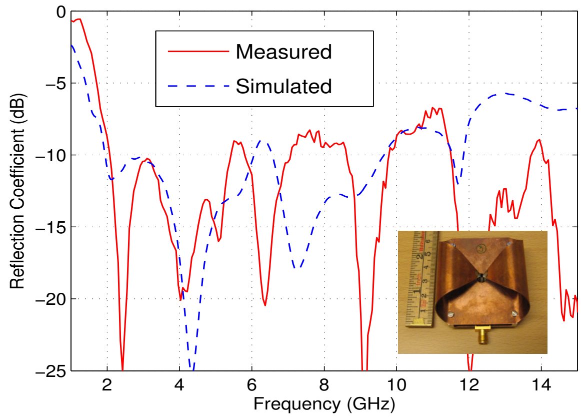

Fig. 4. Reflection coefficient of a 2–15GHz linearly-polarized self-grounded Bow-Tie antenna.

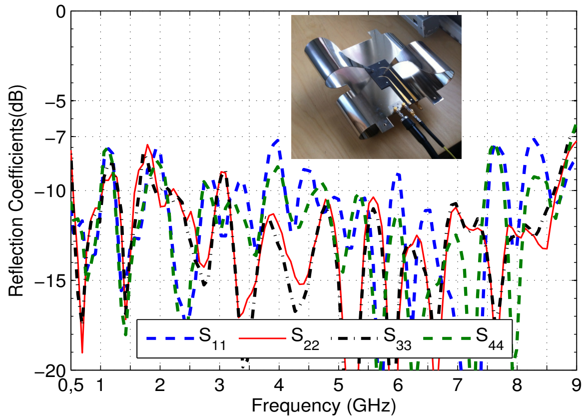

Fig. 5. Reflection coefficient of a 0.5–9GHz MIMO self-grounded monopole array antenna.

A. Low Reflection Coefficient over Wideband

A low reflection coefficient of self-grounded antennas has be achieved over a ultra-wideband. Fig. 4, Fig. 5 and Fig. 6 shows the reflection coefficients of a linearly-polarized self-grounded Bow-tie antenna below -8 dB over 2–15 GHz (7.5:1 bandwidth), a MIMO self-grounded monopole array antenna below -7 dB over 0.5–9 GHz (18:1 bandwidth), and a dual polarized self-grounded Bow-tie antenna below -10 dB over 1.5–3 GHz(2:1 bandwidth), respectively.

B. Fast Time-domain Impulse Response

The self-grounded antenna has a very fast time response due to its characteristic geometry: no multiple resonant geometry. Fig. 7 shows the measured time-domain impulse response when two self-grounded Bow-tie antennas face to each other. It can be seen that there is almost no ringing after the pulse.

C. Good Axial Ratio over Wide Coverage

One of interesting characteristics of the self-grounded Bow-tie antenna is that the axial ratio (AR) of the circularly polarized far-field function of the antenna is good over a wide

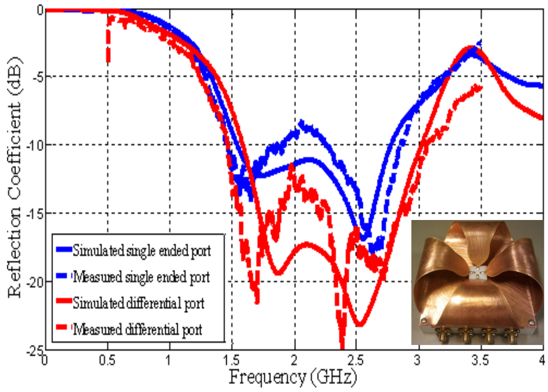

Fig. 6. Reflection coefficient of a 1.5–3GHz dual-polarized self-grounded Bow-Tie antenna.

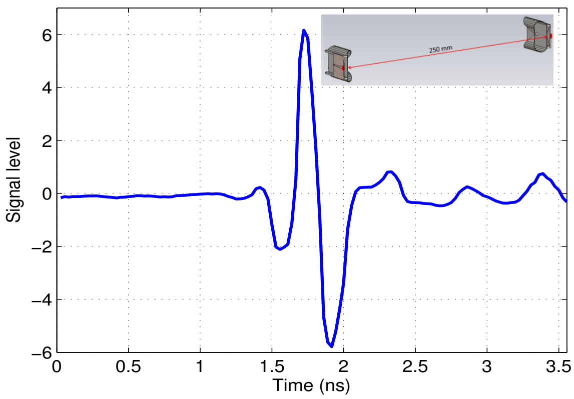

Fig. 7. Measured time-domain impulse response of two self-grounded antennas separated by 250mm in the face-to-face configuration.

coverage with a wideband. Fig. 8 shows the calculated AR based on the simulated far-field function of a 0.5–1.6 GHz dual polarized self-grounded Bow-tie antenna. From it, we can see that over the frequency band, the AR is below -4 dB over $\theta \subset (0, 60°)$. Note that when θ is smaller than 30°, the AR is below -2 dB over the whole band. This characteristic makes the antenna a perfect candidate for receiving antenna for satellite communication and GPS on a moving vehicle, such on boats, on trains and on cars.

D. Constant Phase Center

Due to the self-grounded geometry, the antenna has a stable phase center location, which is similar to the Eleven antenna [11], [12]. Fig. 9 shows the phase center of a 1.5–3GHz dual-polarized Bow-tie antenna. It can be seen that over 1.6–2.2 GHz, the phase center location is within ±2 mm.

E. Good Polarization Balance

By different arrangements, the self-grounded antennas can be used as good MIMO antennas, with a good polarization balance over all directions. The polarization balance is defined as the ratio of power between two orthogonal components, which is a function of direction (θ, φ) [13]. Fig. 10 shows the calculated polarization balance of a 0.4–15GHz MIMO antenna, which shows a good performance.

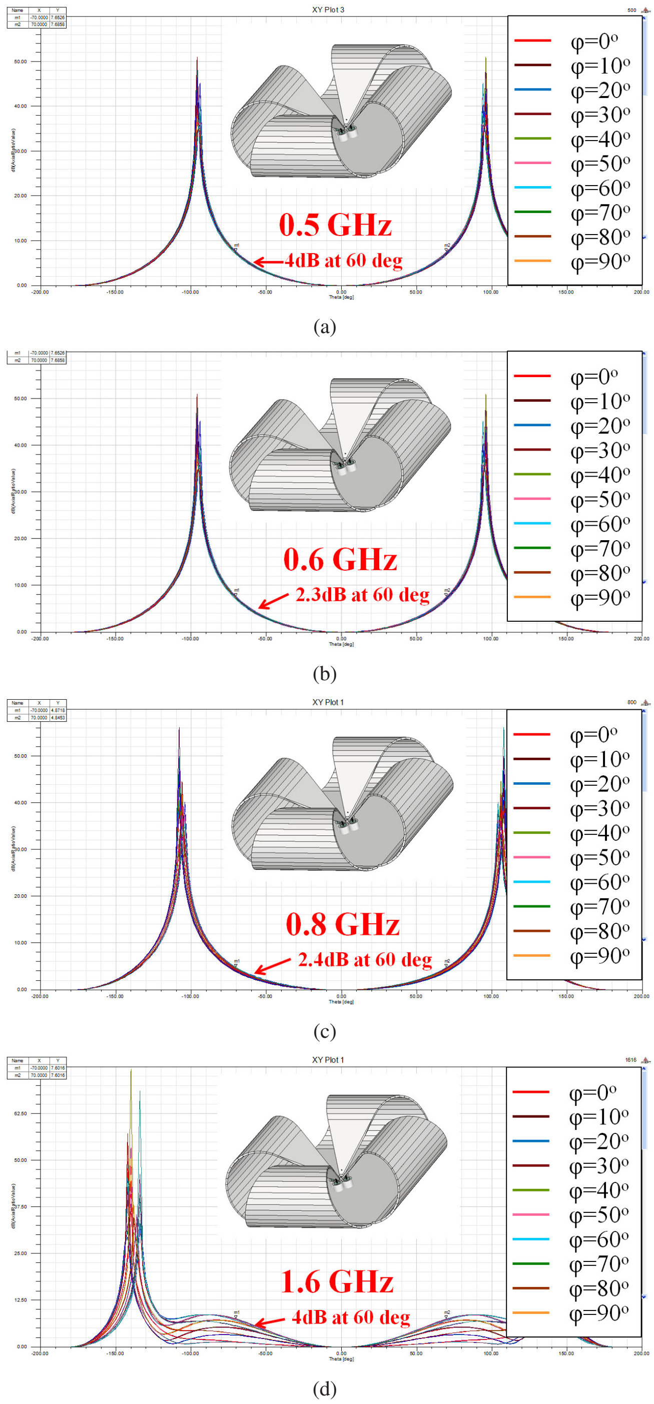

Fig. 8. Simulated axial ratio over $\theta \subset (0, 60°)$ in a frequency range of 0.5–1.6 GHz.

F. High Diversity Gain

Fig. 11 shows the measured and simulated apparent diversity gain with maximal ratio combining (MRC) scheme for the proposed antenna, used as a 2-, 3-, or 4-port MIMO antenna. A high diversity gain has been achieved by this double-sided

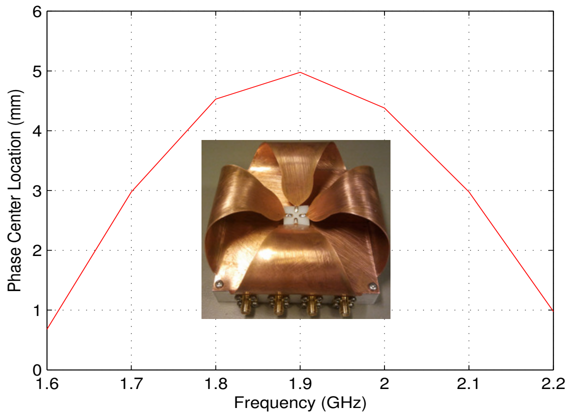

Fig. 9. Calculated phase center location based on simulated radiation function of 1.5–3GHz dual-polarized Bow-tie antenna.

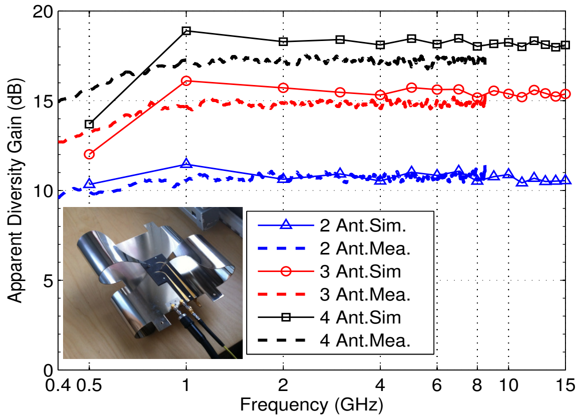

Fig. 11. Apparent diversity gain with maximum ratio combining technique (MRC) using a four-branch double-sided self-grounded antenna.

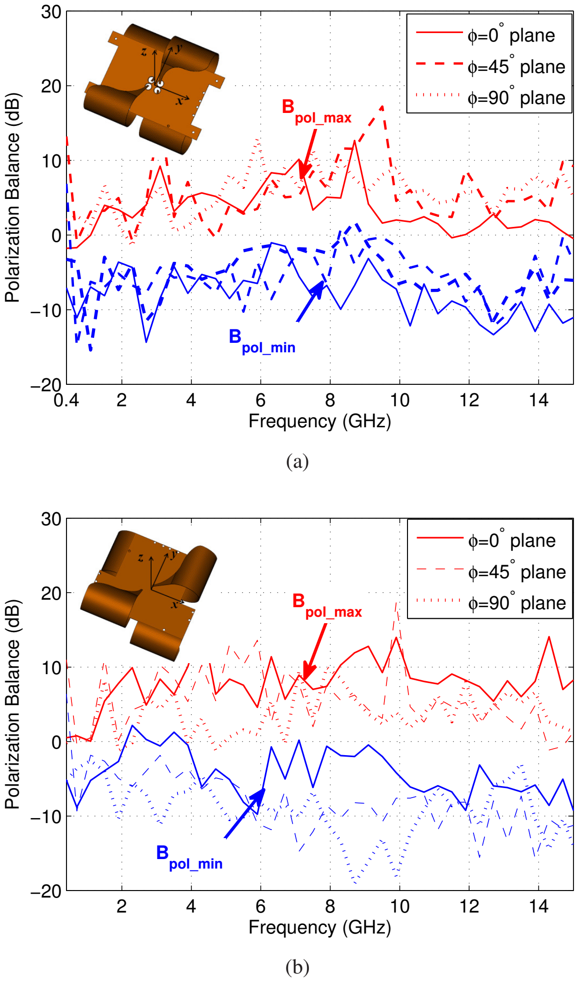

Fig. 10. Calculated polarization balance of (a) the MIMO antenna in [8] and (b) a variation of this MIMO antenna.

tapered self-grounded monopole array arrangement.

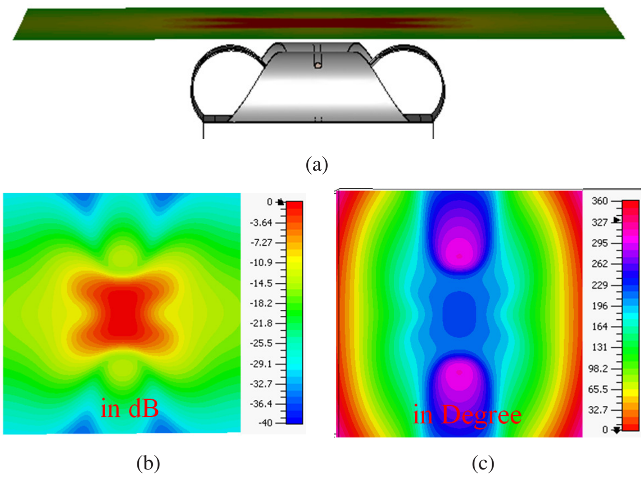

Fig. 12. Simulated aperture distribution of 1.5–3GHz Bow-tie antenna (a): amplitude (b) and phase (c).

G. Near Field Aperture

Fig. 12 shows the near field aperture of the self-grounded Bow-tie antenna, which is a good candidate in near field detection applications.

V. Applications

Due to the flexibility and good performance, the self-grounded antennas have been applied or under investigation to the following areas: i) UWB indoor and through-wall radar with precise ranging and tracking due to the wideband performance, fast time-domain impulse response and the compact size [14]; ii) wideband MIMO systems due to the large coverage, good polarization balance and high diversity gain [8], [15]; iii) stroke diagnosis system due to the good near field aperture distribution [16]; iv) UWB SAR imaging of near field object for industrial process [17], [18]; v) breathing and heartbeat detection [19]. vi) receiving antenna on moving vehicles, such as on boats, trains and cars, because of its good

Axial Ratio over large elevation angles and low profile. More applications will be found to this type of antennas.

VI. Conclusions

We have presented an overview of different arrangements and performances of the self-grounded antennas. We believe that this new type of UWB antenna can find more applications in different areas.

The self-grounded antenna is protected by patents [20], [21].

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