Compact triple band antenna for the aircraft communications application

Jun Ouyang[1], Feng Yang[1]， Biao li[2], Xianfa Tang[2]

1.Department of Microwave Engineering, School of Electronic Engineering,

University of Electronic Science and Technology of China (UESTC),

Chengdu, 610054, P. R. China

2．China academy of engineering physics

Email: antenna_ou@.163.com

Abstract:

In this paper, we present the design of a novel antenna based on the 3-D multi-monopoles antenna for aircraft communications application. The proposed antenna is a triple-band antenna that covers the 121.5 MHz, 243MHz and the 406MHz bands. The antenna is designed in 3-D providing a compact form without compromising its performance. Meantimes, this antenna is designed with low-height, light weight and easy adjusted. The triple resonance frequencies can be adjusted by modifying the length of each antenna arm respectively. It is easily optimized through extensive numerical simulations and experimental prototyping. The antenna performance is shown through the simulated and measured return loss as well as the radiation patterns and efficiency. Its total height is 40cm(≈0.27λmax), The results show good return loss, radiation patterns, and efficiency performance.

Index Terms—3-D antenna, triple-band antenna, easy adjusted monopoles antenna.

I. Introduction

As aircraft communications grow rapidly, there is increasing demand for antennas having compact size, low-height and multiband operation. Especially, the antenna height that also includes the height of ground is the most important parameter for satisfying aircraft aerodynamics.

In mobile communications bands, to meet the miniaturization and aesthetics requirements, various kinds of triple band antenna suitable for WLAN/WiMAX or GSM/DCS operation have been reported. For example, A microstrip line fed slot antennas possess many advantages in [1,2]. The authors have presented a microstrip fed rectangular monopole[3] with a large metallic plate of trapezoid shape placed beneath. A compact slotted CPW fed antenna in [4], embedded by three shape slots produces triple resonant modes at 2.27–2.62, 5.11–5.54 and 6.45–7.64 GHz. A planar rectangular radiation element with horizontal strips[5], printed on an FR4 substrate, is present to achieve triple frequency band operation, covering the WLAN/WiMAX bands. In [6,7], due to its compact size and good impedance bandwidth performance, the meander line antenna is an attractive monopole type antenna.

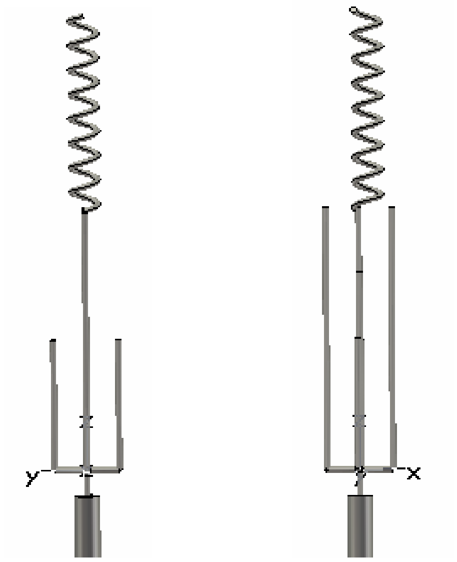
It looks like there are many references for guiding this design. But, detailed studies show that lots of antennas’ grounds contain handset mobile’s circuit ground. Their performances would be verified enormously, if the handset mobile’s circuit ground changed. Meantimes, when the ground is orthogonal with the antenna, the performance, especially in low frequency, is hardly achieved. However, in aircraft communications, antennas are required building on the surface of the airplane. It is means that the antennas’ ground is orthogonal with the antennas. Moreover, for satisfying aircraft aerodynamics, these antenna need be designed having low-height and whip-like.

Therefore, in this paper, a thin (in diameter) , low-height and whip-like triple frequency monopole antenna is proposed, which covers the 121.5 MHz , 243MHz and the 406MHz bands. Its total height is 40cm($\approx 0.27\lambda_{max}$), diameter is 10mm.

II. Antenna Geometry and Simulation Tools

The proposed antenna is illustrated in Fig. 1a, which is a whip-like structure with dimensions of 400×10mm and it must be mounted on a ground plane of size 1200×1200 mm for simulating the airplane platform. Fig. 2 shows the section structure of the antenna. As shown in Fig. 2, the antenna with five branches was adopted. Except the middle branch, each two equal-length branches are place in a plane that is perpendicular to the plane of the other two equal-length branches. The symmetrical structure is used for obtaining omnidirectional pattern. The middle branch should works for the lower band and the other four branches should work with the other two high bands. The simple structure can be manufactured with enameled wire which fixed on the surface a dielectric-rod. It is obvious that this simple structure and principle is convenient for adjusting.

Figure 1. The proposed antenna photo



(a)yoz (b)xoz

Figure 2. The section structure of the proposed antenna

For the limit of the antenna height, spiral line is used for obtaining longer electric length. Simulated and experimental results indicate that it is feasible to reduce the antenna height by enlarging the turn of loop.

For its simple structure, the antenna can be easily simulated by the method of moments (MOM). A wire-to-surface junction basis function[8] is used to calculate wire monopoles on finite conducting plates. For an arbitrarily shaped perfectly conducting body with attached wires, when MOM being implemented, the induced electrical currents on the platform, along the wires and at the junction region can be expanded with the well-known RWG basis functions, the triangle type basis functions and the junction basis functions. The formulas of these three kinds of functions are shown in (1), (2), and (3) respectively:

$$\vec{f}_n^{\,s}(\vec{r}) = \begin{cases} \dfrac{l_n}{2A_n^{\pm}}\vec{\rho}_n^{\,\pm} & \vec{r} \in T_n^{\pm} \\ 0 & else \end{cases} \tag{1}$$

$$\vec{f}_n^{\,w}(\vec{r}) = \begin{cases} \dfrac{\vec{\rho}_n^{\,\pm}}{l_n^{\pm}} & \vec{r} \in W_n^{\pm} \\ 0 & else \end{cases} \tag{2}$$

$$\vec{f}_n^{\,j}(\vec{r}) = \begin{cases} -\dfrac{1}{\alpha_n}\cdot\dfrac{\left[1-\left(1-\eta_n^k\right)^2\right]}{\rho_k^2}\vec{\rho}_k & \vec{r} \in T_n^k \\ \dfrac{\vec{\rho}_n^{\,-}}{l_n^-} & \vec{r} \in W_n^- \\ 0 & else \end{cases} \tag{3}$$

where $k = 1,2,\ldots,N_n^{jp}$ and N_n^{jp} is the number of the patches connected with the junction point. The subscript *n* denotes the function no., and the superscripts *s*, *w*, and *j* are used to index "surface", "wire" and "junction" respectively. In (3), the position vector $\vec{\rho}_n = \vec{r}_w - \vec{r}_O$ is directed from the junction point to the source/field point on the wire segment, while the other position vector $\vec{\rho}_k = \vec{r}_s - \vec{r}_O$ is pointed from the junction point to the source/field point on the junction patches. For convenience and accuracy, in (3), a linear function rather than the equivalent-moment pulse function is defined on the wire segment. The meanings of the area ratio η_n^k and other symbols in (1) – (3) can be found in numerous relevant literatures and will not be listed here.

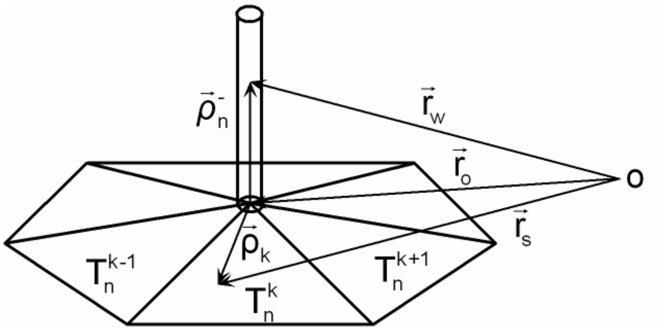


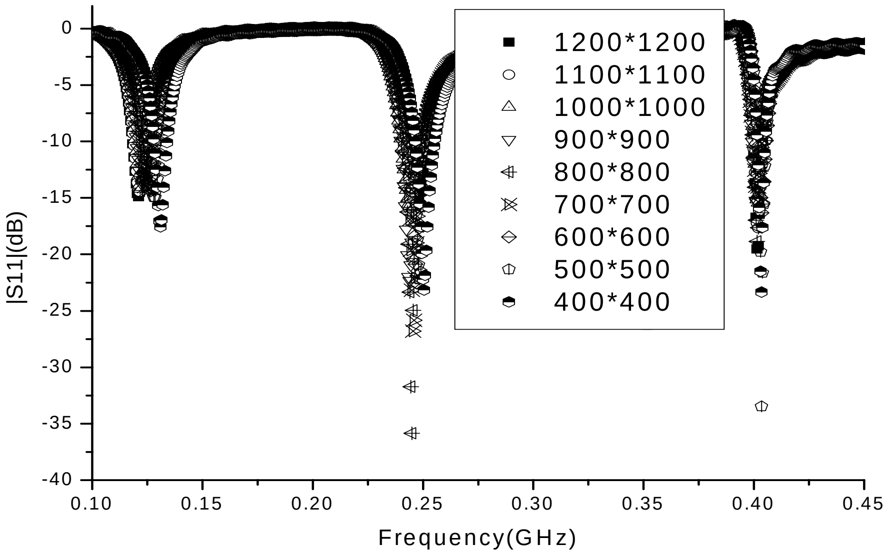
Fig. 3. Wire-to-surface junction basis

III. Results and Discussions

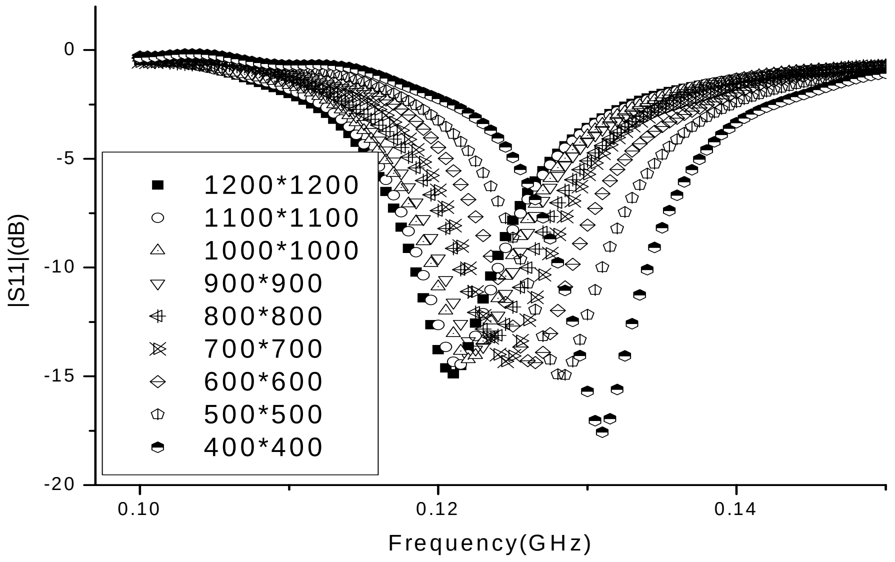
A. Antenna Optimization

1) Effect of the Ground Plane

Fig. 4 shows the return loss of the proposed antenna with different ground plane dimensions. From this figure, in the lowest frequency, the resonance frequencies of this antenna are sensitive to the size of ground plane. But, they become stabilization when the size of ground plane extends to 1200mm×1200mm (≈0.5 λ_{max}). Therefore, the design of antenna must contain a large enough ground plane for acting the real aircraft platform.



（a）All frequencies

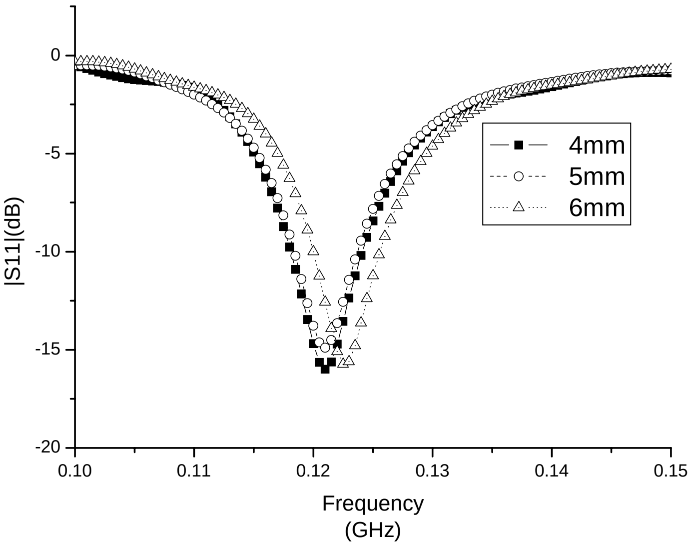


（b）the lowest frequency

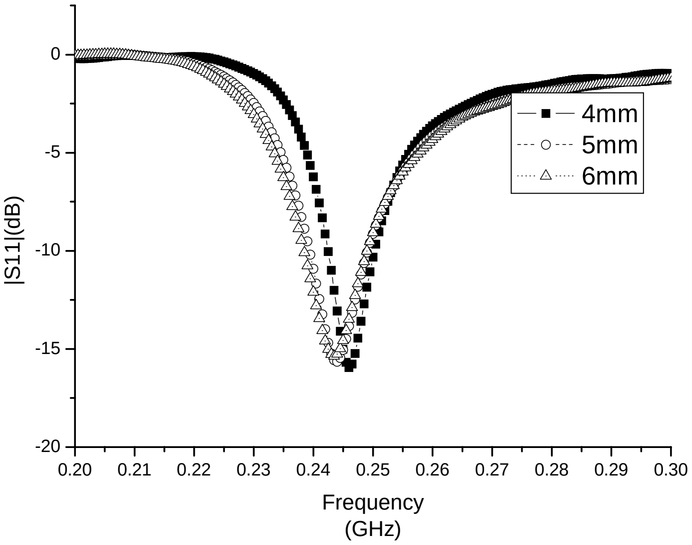
Figure 4. the return loss of the proposed antenna with different ground plane dimensions.

2) Effect of branches distance(also the radius of this antenna) :

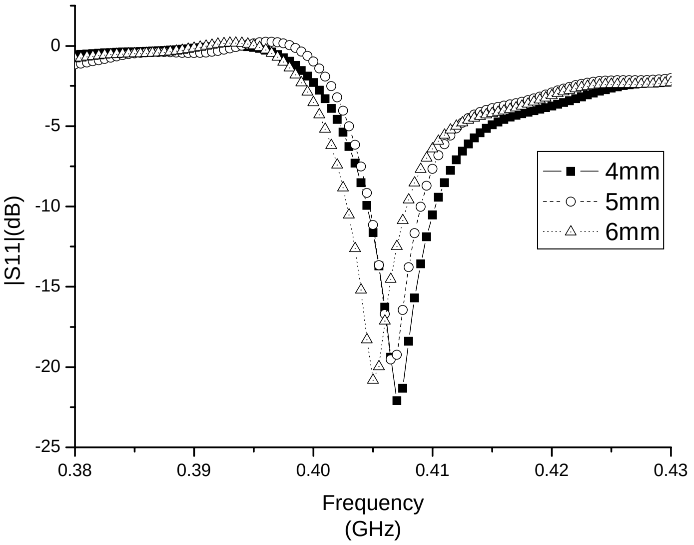
Fig. 5 shows the return loss of the proposed antenna with different distances between each branch. This research can help us to choice a appropriate diameter. From this figure, the resonance frequencies of this antenna have a little various.



(a) lowest frequency



(b) middle frequency



(c) highest frequency

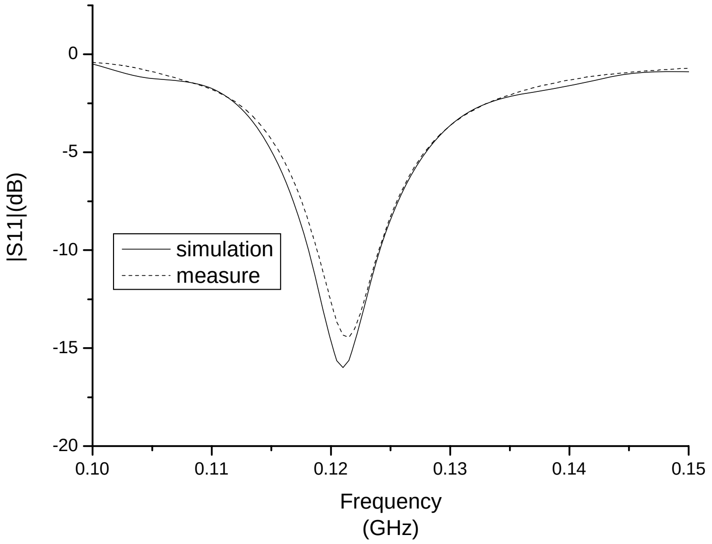
Figure 5. the return loss of the proposed antenna with different distances between each branch

B. Antenna Characteristics

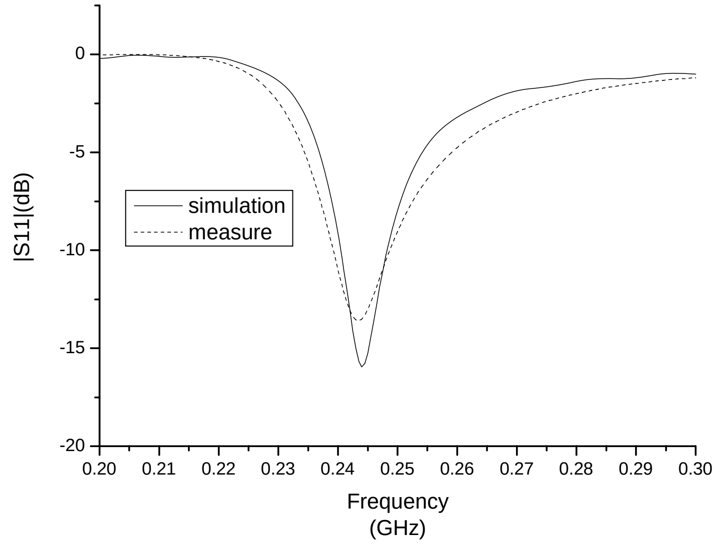
This section presents the antenna characteristics of the best achieved design in the frequency range of interest. These are: antenna's return loss, efficiency, and radiation patterns. The middle branch works for the lowest band and the total length is 400mm. The other four branches, whose lengths are 147mm and 285mm respectively, work with the other two high bands. The branches distance is 5mm.

1) Return Loss:

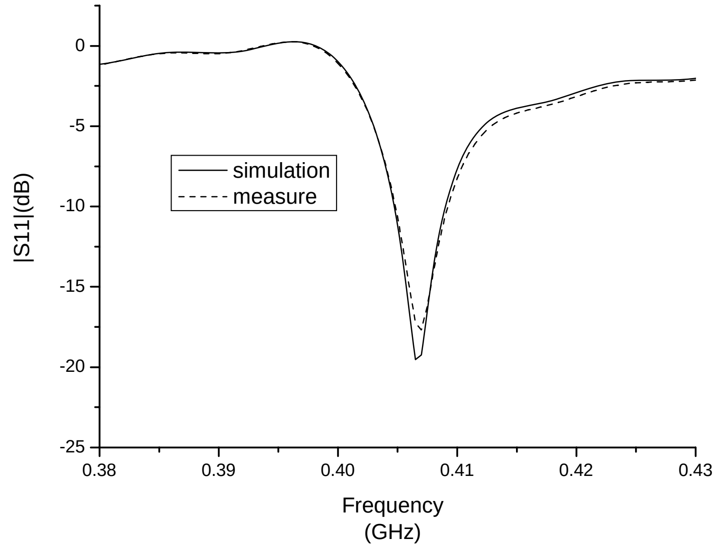
Fig. 6 shows the measured and the simulated return loss of the antenna for a frequency sweep of 100 MHz to 450 MHz. The results show an excellent agreement between the measurements and the simulations. The antenna features a very good match and broad bandwidth at all frequencies of interest.



(a) lowest frequency



(b)middle frequency



(c)highest frequency

Figure 6. the measured and the simulated return loss of the antenna

2) Efficiency:

Table I presents the computed total efficiency of the antenna in different frequency bands. The total efficiency is defined as the ratio between the radiated power and the total incident power at the feed, and it takes into account both mismatch losses and ohmic losses

	121.5MHz	243MHz	406MHz
efficiency	94.2%	95.3%	97.4%
Gain(dB)	1.1dBi	3.7dBi	4.3dBi

3) Radiation Patterns:

The radiation patterns at 121.5, 243, and 406MHz are shown in Fig. 7. The antenna was oriented with respect to the coordinates system as shown in the inset figure of Fig. 2. The results are presented in the xoz plane, which is the vertical plane. In the horizontal plane, the antenna pattern is omnidirectional.

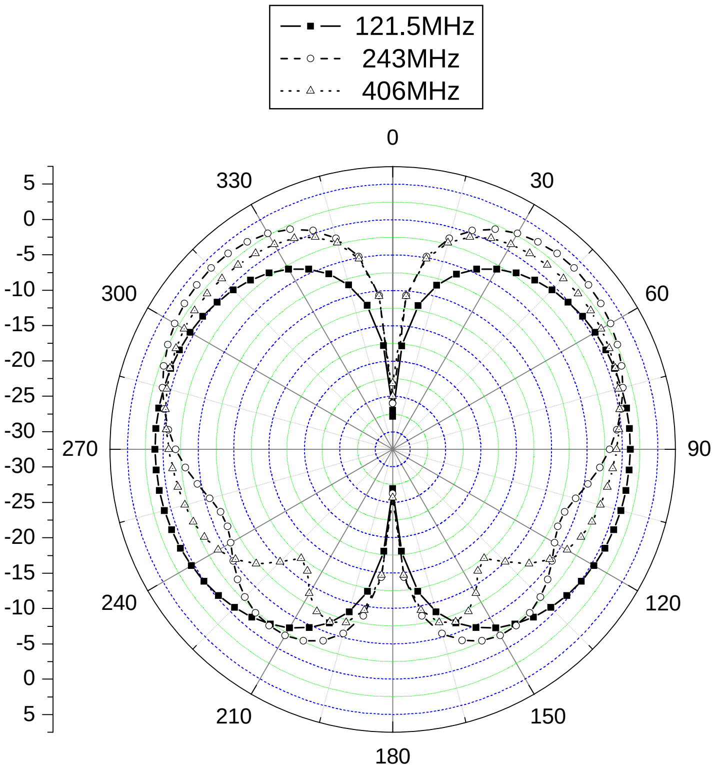


Figure 7. The radiation patterns at 121.5, 243, and 406MHz

IV. Conclusion

A novel antenna based on the 3-D multi-monopoles antenna for aircraft communications application is present here. The proposed antenna covers the 121.5 MHz, 243MHz and the 406MHz bands with low-height, light weight and easy adjusted. The total height of this antenna is 40cm($\approx 0.27\lambda_{max}$). The triple resonance frequencies can be adjusted by modifying the length of each antenna arm respectively. The size of the ground plane and the branch distance are optimized for obtaining a good match at the frequencies of interest in real situation. The antenna performance is shown through the simulated and measured return loss as well as the simulated radiation patterns and efficiency.

Acknowledgments

This work was supported by the postdoctoral Science Foundation of China (No. 20090461325), the National Natural Science Foundation of China (No.61001029)，Partly Supported by the National Natural Science Foundation of China (No.10876007), ministerial fund (No. 9140A01020109DZ0202)

Reference

[1]Jan, J.Y., and Su, J.W. Bandwidth enhancement of a printed wide-slot antenna with a rotated slot, IEEE Trans. Antennas Propag., 2005, 53, pp. 2111–2114.

[2] Chen, W.-S., and Ku, K.-Y. Band-rejected design of printed open slot antenna for WLAN/WiMAX operation, IEEE Trans. Antennas Propag., 2008, 56, (4), pp. 1163–1169.

[3] Pan, C.-Y., Horng, T.-S., Chen., W.-S., and Huang, C.-H. Dual wideband printed monopole antenna for WLAN/WiMax applications, IEEE Antennas Wirel. Propag. Lett., 2007, 6, pp. 149–151.

[4] Liu, W.C., and Liu, H.J. Compact tri-band slotted monopole antenna with asymmetrical CPW grounds, Electron. Lett., 2006, 42, pp. 840–842.

[5] K.G. Thomas and M. Sreenivasan. Compact triple band antenna for WLAN/WiMAX applications, Electron. Lett., 2009, 45, (16), pp. 811–813.

[6] Chen, H.D. Triple-band triangular-shaped meander monopole antenna with two coupled line. Microwave Opt. Technol. Lett. , 2003, 37, (3), pp. 232–234.

[7] B. Sun, Q. Liu and H. Xie. Compact monopole antenna for GSM/DCS operation of mobile handsets. Electron. Lett. , 2003, 39, (22), pp.1562-1563.

[8] X.Z.Zong, Z.P. Nie and X.F.Que. Numerical Analysis of Cone/Pyramid-shaped Antennas Using Wires/Surface-to-surface Junction Basis. IEEE Trans. Antennas Propag. 2009, 57(4), pp:1150–1157.