第 21 卷 第 4 期
2003 年 12 月

应 用 科 学 学 报
JOURNAL OF APPLIED SCIENCES

Vol. 21, No. 4
Dec. 2003

Article ID: 0255－8297(2003)04－0334－05

A Novel Method for Designing Dual-Frequency Slot Patch Antennas with Two Polarizations

WU Di[1], OHISHIBASHI Hidekazu[2], SEO Kazuyuki[2], INAGAKI Naoki[3]

(1. *Department of Communication Engineering, Shanghai University, Shanghai* 200072, *China*;
2. *Kojima R&D Center, Kojima Press Industrial Co Ltd, Aichi* 470—0207, *Japan*;
3. *Nagoya Institute of Technology, Nagoya* 466—8555, *Japan*)

Abstract: This paper presents a new method for designing a dual-frequency patch antenna with circular and linear polarizations. Dual-frequency operations are behaved by etching two narrow slots close to the radiating edges of a rectangular patch. The circular polarization at the lower resonant frequency of the dual-frequency antenna can be achieved by setting a perturbation segment at an appropriate location in the patch element, and placing the feed point on the diagonal axis. Several experimental results of a designed antenna show the good characteristics for circular and linear polarizations at both resonant frequencies.

Key words: dual-frequency; slot patch antennas; linear polarization; circular polarization

CLC number: TN821.1 **Document code**: A

新的双频双极化开槽微带天线的设计方法

吴　迪[1]， 大石桥秀和[2]， 濑尾和之[2]， 蹈垣直树[3]

(1. 上海大学 通信学院，上海 200072；2. 小岛总合研究所，爱知县 470—0207，日本；
3. 名古屋工业大学，名古屋市 466—8555，日本)

摘　要：提出了一种同时具有圆极化和线极化的双频新型开槽微带天线的设计方法. 天线双频工作是通过分别在靠近方形微带天线的两个辐射边处各开一个平行的窄槽来实现的. 在较低的谐振频率处圆极化的获得是通过在天线辐射单元上适当地设置摄动元素，并将馈电点移到辐射单元的对角线上. 一个设计天线的测试结果给出了该天线在两个谐振频率上具有很好的圆极化及线极化的天线性能.

关键词：双频；开槽微带天线；线性极化；圆极化

In radar and communication systems, dual-frequency operations are often required. Specially, in modern mobile global position system(GPS), it will be desirable that one of two frequencies is the circular polarization. Planar antenna has been investigated for multi-frequency very well since it is advantageous in low cost, low weight and conformability. Early dual-frequency planar antenna is multilayered stacked-patch structure, and the radiating element is used to be circular[1], annular[2], rectangular[3] and triangular patches[4]. Recently, a dual-frequency antenna is introduced in which the structure is single layer patch with two slots close to the radiating edges, and good performances of simultaneous impedance matching and gain are demonstrated for both resonant frequencies. However, all the conventional investigations are only for the case in which the antenna polarization is

Received date: 2002－11－11; **Revised date**: 2002－12－03
Foundation item: Project Supported by Science and Technology Foundation of Shanghai Higher Education(03AK46)
Biography: WU Di(1964－), male, Heilongjiang, Associated Professor, Doctor.

linear, while the dual-frequency antenna with circular polarization has not been touched yet.

In this paper, we present a design method of a dual-frequency antenna with circular and linear polarizations based on the conventional investigation for the dual-frequency linear polarization antenna[5~7]. Two resonant frequencies are determined by adjusting the size of the patch element and the slot, as well as the location of the slot in the element. The key to obtain a circular polarization for an antenna is to satisfy the condition for exciting circular polarization, i. e. the circular polarization can be excited by setting the perturbation segment Δ_s at an appropriate location in the patch element, and by placing the feed point on the diagonal axis. We have experimentally obtained the circular and the linear polarizations at both lower and upper frequencies, and some experimental results will be demonstrated on the reflection loss at input port and the radiation pattern of the antenna.

1 Configuration of conventional dual-frequency patch antenna

Figure 1 shows a configuration of a conventional dual-frequency antenna with linear polarization. Two resonant frequencies are behaved by etching two slots close and parallel to the radiating edges, and the lower resonant frequency is determined by the outline size of the patch element, while the upper resonant frequency is determined by the size and the position of the two slots in the patch element. Because the slots are closely located to the radiating edges, a minor perturbation of the TM_{10} mode can be expected. As for unperturbed TM_{30} mode, since the slots are located where the current shall be significant, the current will be strongly modified, and a perturbed TM_{30} radiation pattern similar to the TM_{10} mode can be obtained.

Our object in this investigation is to obtain a dual-frequency antenna with both polarizations in which the lower frequency is with a circular polarization and the upper frequency is with a linear polarization. For a square patch antenna with area of S fed by one port, a way to excite a circular polarization is to extend the length of two parallel subtends of the patch element in order to set a perturbation segment Δ_s, and place the feeding point on the diagonal axis. When an appropriate perturbation is selected, a circular polarization with a good axial ratio can be obtained.

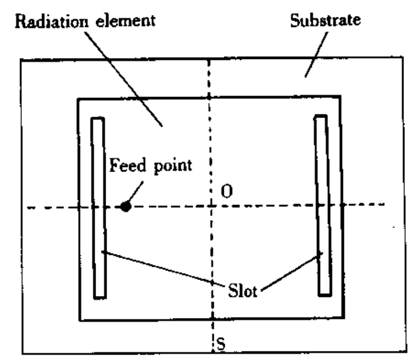

Fig. 1 Configuration of conventional dual-frequency antenna

2 Designing for dual-frequency slot patch antennas with two polarizations

In a conventional investigation for dual-frequency with linear polarization[5~7], to ensure a good radiation efficiency at both frequencies, the aspect ratio between the two sides of the patch is taken in the range

$$0.7<\frac{L}{W}<0.8 \tag{1}$$

and the lower frequency is determined by

$$f_L=\frac{c}{2(W+\Delta W'+\Delta W'')\sqrt{\varepsilon_e(L/t,\varepsilon_r)}} \tag{2}$$

where c is the velocity of light in free space. ε_e is the effective permittivity given by

$$\varepsilon_e(x,y)=\frac{y+1}{2}+\frac{y-1}{2}\left(1+\frac{10}{x}\right)^{-\frac{1}{2}} \tag{3}$$

and

$$\Delta W'=W\left(1.5\frac{w}{W}-0.4\frac{l}{L}\right) \tag{4}$$

$$\Delta W''=g\left(\frac{L}{t},\varepsilon_r\right)t \tag{5}$$

here

$$g(x,y)=\frac{1}{\pi}\frac{x+0.336}{x+0.556}\cdot \left[0.28+\frac{y+1}{y}(0.274+\ln(x+2.518))\right] \tag{6}$$

and the upper frequency is determined by

$$f_{\mathrm{H}}=\frac{c}{2(L-2l+d)\sqrt{\varepsilon_e(w/t,\varepsilon_r)}} \tag{7}$$

In above expression, the parameters of W, L, t, w, d, l are referred to Fig. 2, and the ε_r is the dielectric constant of the substrate. However in this study, in order to obtain a circular polarization at the lower resonant frequency, the aspect ratio of the outline size of the patch will be changed so that the mentioned formulas above will not be completely satisfied.

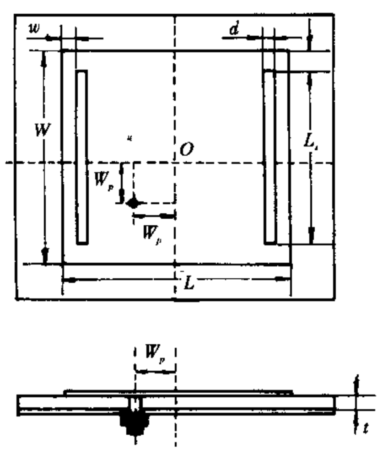

Fig. 2 Configuration of dual-frequency antenna with both polarizations

We present a design method for dual-frequency slot patch antennas with two polarizations as follows

- Step1 Design a square patch antenna with the desirable lower frequency f_{10} by using a conventional method.
- Step2 Etch two slots close and parallel to the radiating edges to behave the dual-frequencies operation by using Eq. (7). However the lower resonant frequency f_{10} will change, since the two slots modify the current distribution of the TM_{10}.
- Step3 Adjust the size of the antenna element to obtain the desired lower resonant frequency.
- Step4 Adjust the length and the width of the slots to obtain the desired upper resonant frequency f_{30}.
- Step5 Set perturbation segment and place the feed point on the diagonal axis of the antenna element to obtain the circular polarization at the lower resonant frequency f_{10}.

3 Experimental results and discussion

We experimentally designed a dual-frequency patch antenna with two polarizations. Figure 2 shows the configuration of the antenna, and the specifications are listed in Table 1. In this configuration of the antenna, we extended the L edge of the patch antenna to set the perturbation segment, and placed the feed point on the diagonal axis to achieve the circular polarization.

Table 1 Specifications of a dual-frequency patch antenna with two polarizations

	GPS	VICS
Frequency/GHz	1.575	2.5
Polarization	Circular	Linear
Return loss	−15	−15
Gain	3dBic	5dB$_1$

Figure 3 shows a measured reflection loss of a designed dual-frequency antenna fed by 50Ω coaxial probe. From this figure, it can be observed that two resonant frequencies are achieved at desired frequencies 1.575 GHz and 2.50 GHz, which will be employed to mobile global position system (GPS) and vehicle information & communication system (VICS), and a good simultaneous impedance matching was obtained for reflection loss values −17dB at 1.575 GHz and −27dB at 2.5 GHz.

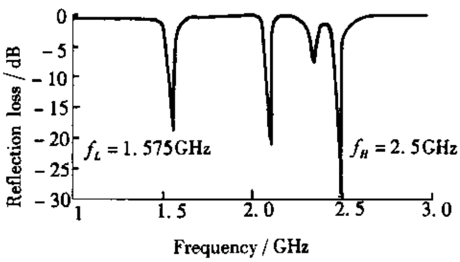

Fig. 3 Frequency characteristics of reflection loss

Figure 4 shows the axial ratio variation with the frequency for this designed antenna. It is seen that the best value of the axial ratio is about 1dB at 1.575 GHz.

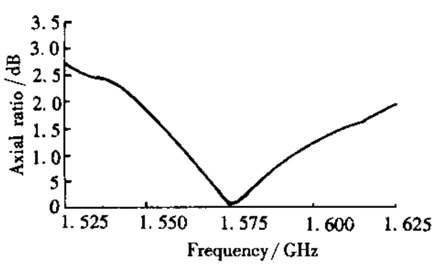

Fig. 4 Frequency characteristics of axial ratio

Figure 5 shows the measured impedance characteristic of the antenna in correspondence with Fig. 3. It demonstrated that a perturbation is set for circular polarization at lower frequency 1.575 GHz.

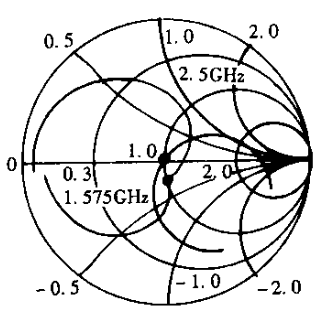

Fig. 5 Frequency characteristics of input impedance

Figure 6 shows the radiation pattern of the circular polarization of the designed antenna at the lower resonant frequency 1.575 GHz. In this figure, we used the unit [dBic] for gain, which can be calculated as follows

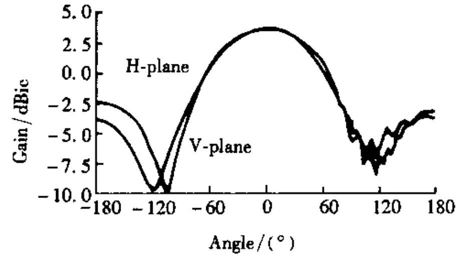

Fig. 6 Radiation pattern of circular polarization

$$G[\text{dBic}]=G_{\max}[\text{dBi}]+20\log\left[\frac{1}{\sqrt{2}}\left(1+\frac{1}{10^{AR/20}}\right)\right]$$

where, $G_{\max}$[dBi] denotes the measured maximum gain in [dBi], AR is the measured axial ratio. A gain of 3.7[dBic] was found for patch antenna with circular polarization at 1.575 GHz.

Finally, the radiation pattern of the linear polarization at the upper frequency 2.5 GHz is shown in Fig. 7. This is the perturbed TM_{30} mode, however, because the two slots exist in the patch, the shape of the radiation pattern of the perturbed TM_{30} mode becomes similar to that of the TM_{10} mode. A gain of 5[dBi] was obtained for patch antenna with linear polarization at 2.5 GHz.

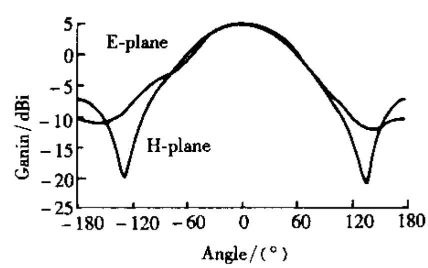

Fig. 7 Radiation pattern of linear polarization

4 Concluding remarks

A novel design method for a dual-frequency patch antenna with both circular and linear polarizations is presented in this paper. Two resonant frequencies are behaved by etching two slots close to the radiating edges in the rectangular patch, and the circular polarization at the lower resonant frequency is achieved by setting a perturbation segment in the patch element, and by placing the feed point on the diagonal axis. A dual-frequency antenna with both polarizations, which will be used to GPS and VICS for mobile communication, is designed by using presented method. As for measured results, it demonstrated that the designed antenna has two resonant frequencies, in which one is a circular polarization with an axial ratio 1[dB] and gain 3.7[dBic] at the lower frequency, and the other is a linear polarization with 5[dBi] at the upper frequency.

References:

[1] Long S A, Walton M D. A dual-frequency stacked circular-disc antenna [J]. IEEE Trans Antennas Propagat, 1979, AP-27:270-273.

[2] Dahele J S, Lee K F, Wong D P. Dual frequency stacked annular-ring microstrip antenna[J]. IEEE Trans, 1987, AP-35(11):1281-1285.

[3] Wang J, Fralich R, Wu C, et al. Multifunctional aperture coupled stack antenna[J]. Electron Lett, 1990,26(25):2067-2068.

[4] Mirschekar-syankal D, Hassani H R. Characteristics of stacked rectangular and triangular patch antennas for dual band application[A]. IEE 8th ICAP[C]. 1993. Edinburgh.

[5] Maci S, Biffi Gentili G, Avitabile G. Single-layer dual-frequency patch antenna[J]. Electronics Letters, 1993,29(16):1441-1443.

[6] Maci S, Biffi Gentili G, Piazzesi P, et al. Dual-band slot-loaded patch antenna[J]. IEEE Proceedings H, 1995,142(3):225-232.

[7] Maci S, Biffi Gentili G. Dual-frequency patch antennas[J]. IEEE Antennas and Propagation Magazine, 1997,39(6):13-20.

下期发表论文摘要预报

自适应调制中一种新的盲检测算法的研究

方　昕，尤肖虎，高西奇

（东南大学 移动通信国家重点实验室，江苏 南京　210096）

摘　要：在基于包传输的自适应调制系统中，提出了一种新的调制方式分类的算法，即利用接收到的包数据在星座图上的每一个点周围区域的分布概率来确定调制方式，并通过分析对该算法参数的选择进行了讨论，仿真和分析结果表明此算法对自适应调制系统是非常有效的，且复杂度很低，适用于实时处理.

如 何 学 习 天 线 设 计

天线设计理论晦涩高深，让许多工程师望而却步，然而实际工程或实际工作中在设计天线时却很少用到这些高深晦涩的理论。实际上，我们只需要懂得最基本的天线和射频基础知识，借助于 HFSS、CST 软件或者测试仪器就可以设计出工作性能良好的各类天线。

易迪拓培训(www.edatop.com)专注于微波射频和天线设计人才的培养，推出了一系列天线设计培训视频课程。我们的视频培训课程，化繁为简，直观易学，可以帮助您快速学习掌握天线设计的真谛，让天线设计不再难…

HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助你快速学习掌握如何使用 HFSS 软件进行天线设计，让天线设计不再难…

课程网址：http://www.edatop.com/peixun/hfss/122.html

CST 天线设计视频培训课程套装

套装包含 5 门视频培训课程，由经验丰富的专家授课，旨在帮助您从零开始，全面系统地学习掌握 CST 微波工作室的功能应用和使用 CST 微波工作室进行天线设计实际过程和具体操作。视频课程，边操作边讲解，直观易学；购买套装同时赠送 3 个月在线答疑，帮您解答学习中遇到的问题，让您学习无忧。

详情浏览：http://www.edatop.com/peixun/cst/127.html

13.56MHz NFC/RFID 线圈天线设计培训课程套装

套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

详情浏览：http://www.edatop.com/peixun/antenna/116.html

关于易迪拓培训：

易迪拓培训(www.edatop.com)由数名来自于研发第一线的资深工程师发起成立，一直致力和专注于微波、射频、天线设计研发人才的培养；后于 2006 年整合合并微波 EDA 网(www.mweda.com)，现已发展成为国内最大的微波射频和天线设计人才培养基地，成功推出多套微波射频以及天线设计经典培训课程和 ADS、HFSS 等专业软件使用培训课程，广受客户好评；并先后与人民邮电出版社、电子工业出版社合作出版了多本专业图书，帮助数万名工程师提升了专业技术能力。客户遍布中兴通讯、研通高频、埃威航电、国人通信等多家国内知名公司，以及台湾工业技术研究院、永业科技、全一电子等多家台湾地区企业。

我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验

※ 一直专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 视频课程、既能达到了现场培训的效果，又能免除您舟车劳顿的辛苦，学习工作两不误

※ 经验丰富的一线资深工程师主讲，结合实际工程案例，直观、实用、易学

联系我们：

※ 易迪拓培训官网：http://www.edatop.com

※ 微波 EDA 网：http://www.mweda.com

※ 官方淘宝店：http://shop36920890.taobao.com