Small Four-Beam Switched Slot Yagi-Uda Antenna

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1. Introduction

By the rapid spread of the internet, high-speed wireless LAN is required. In high-speed wireless applications, the throughput of communication is degraded by multi-path fading. A beam switched antennas can improve the degradation of throughput by using the effect of directional diversity [1]. Various beam switch type multi-sector antennas have been proposed. The multi-sector antennas which used monopole Yagi-Uda antennas [2], etc. as directional antenna elements were proposed. However, these kinds of antennas have three-dimensional structure including projections and are unsuitable for mass productions. On the other hand, the planer multi-sector antennas by using slot Yagi-Uda antennas which used the printed circuit board was proposed [3]. However, this antenna needs several directors and sector switches with large insertion loss for each sector. In this paper, we propose beam switched small antennas using slot Yagi-Uda antennas with RF switches for wireless LAN (802.11a). The beam direction of this antenna can be changed to quad orthogonal directions by exchanging the role of director and reflector with RF switches.

2. Printed slot Yagi-Uda antenna

Firstly, we describe printed slot Yagi-Uda antenna (PSYUA) as antenna elements for beam switched antenna. The structure of PSYUA is shown in Fig.1. The rectangular radiation slot is fabricated in the dielectric substrate (FR-4, εr=4.2, h=1.0mm, t=18μm) and is fed by electromagnetic coupling with 50Ω micro strip line (WM=1.8mm). Micro strip line is offset MO mm in the direction of +X from the center of the radiation slot and is terminated by open end stub of length ML mm. Design frequency is set to 5.2GHz mainly used by IEEE802.11a, and antenna size (grand plane) is made into the square below 40mm (=LG) which can be installed in PC card slots. The radiation slot resonates about half wavelength in the waveguide (Equivalent dielectric constant $\varepsilon_{eff} = (\varepsilon_r+\varepsilon_0) / 2$, [3]). The director slot, the radiation slot, and the reflector slot are arranged at quarter wavelength interval. The length of the director slot and the reflector slot is set to 18.5mm and 20.5mm, respectively. The measurement and calculation value of input characteristics of PSYUA are shown in Fig. 2. The calculation is used by FDTD method. Although the measurement and calculation include some errors by difference of the physical parameter (the ratio of substrate dielectric constant) of substrate etc., the same tendency is shown. The frequency band width of antenna is about 300MHz (5.0-5.3GHz, this band is available for IEEE802.11a). The radiation pattern is shown in Fig. 3. Although the measurement and calculation have differences by connecting the connector and the coaxial cable to the feed port, the almost same tendency is shown. Inclination of radiation pattern is obtained in YZ plane and the radiation direction leans to the director slot side. Actual measurement antenna gain is shown in Table. 1.

3. Beam switched antenna

As shown in Fig. 1, the directional antenna can be given if the director and the reflector slot are arranged. Furthermore, symmetrical directivity can be obtained by exchanging the position of the director and the reflector slot. Therefore, in case of the printed slot antennas, it is possible to change directivity by changing the length of the parasitic slot arranged in front and back of the radiation slot, and making it operate for the director and the reflector. As shown in Fig. 4, the parasitic slot length (LP1+LP2+GP=20.5mm) to operates as reflector is arranged in front and back of the radiation slot. In one parasitic slot, if short-PIN is arranged in the position of the slot length (LP1= 18.5mm) which

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operates as director, this one parasitic slot can operate as director, and this antenna can operate as slot Yagi-Uda antenna.

Secondly, we demonstrate the case to implement the SPDT MMIC switch instead of short-PIN. In the case of this MMIC switch, the reactance element is contained in addition to internal FET, and this switch cannot operate as a changeover switch simply. In slot Yagi-Uda antenna, if the reactance component of the parasitic slot is capacity, the parasitic slot works as director. On the other hand, in case of inductive, the parasitic slot works as reflector. Therefore, the synthetic reactance component of parasitic slot and MMIC switch can change operation of director and reflector by capacitive or inductive. As shown in Fig. 5, when MMIC SPDT switch is mounted, the impedance of the parasitic slot Z_P can be expressed as follows.

$$Z_P = Z_{LP1} + Z_{SW} + Z_{LP2} \qquad (1)$$

$$\mathrm{Im}(Z_P) < 0 \qquad (2)$$

$$\mathrm{Im}(Z_P) > 0 \qquad (3)$$

Z_{LPn} : Impedance of the parasitic slot (Length :n)

Z_{SW} : Impedance of MMIC SPDT Switch

If we determine that the length of LP1 and LP2 satisfy the conditions of (2) or (3) by change of the impedance (open and short) of MMIC switch, operation of director or reflector can be changed. The measurement result of YZ plane radiation pattern in case of mounting MMIC SPDT switch (NEC uPG2022TB) in two parasitic slots is shown in Fig. 6. In the case of the sector antenna which director and reflector need for each radiator, miniaturization is difficult [3]. On the other hand, the parasitic slots can be shared by change of the function of director and reflector by MMIC switch and antenna size can be miniaturized.

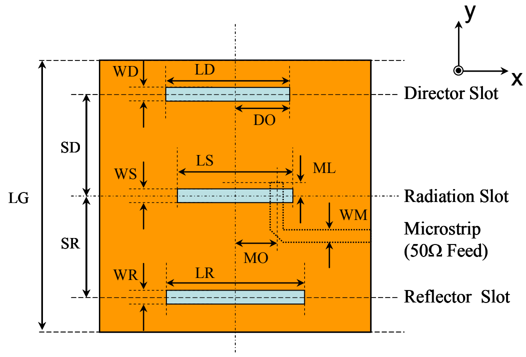
In order to change in the four directions, as shown in Fig. 7, two radiation slots are arranged to a rectangular cross, and 50ohm micro strip feed line is changed by SPDT switch. Similarly, four parasitic slots are also arranged to a rectangular cross, and are operated as director and reflector. As shown in Fig. 7, the printed cross slot Yagi-Uda antenna (PCSYUA) which mounted the MMIC SPDT switch in the parasitic slot is proposed. For example, when leaning directivity to direction #1, the switch is set up so that parasitic slot #1 works as director and others parasitic slots work as reflectors. The input characteristics of PCSYUA with MMIC switch are shown in Fig. 8. In all sectors, the frequency band is more than 200MHz (5.1-5.3GHz). Radiation pattern of PCSYUA with switch is shown in Fig. 9. In all directions, directivity leans to the director side and PCSYUA is operating as slot Yagi-Uda antenna. The antenna gain of PCSYUA with switch is shown in Table 2. Although the antenna gain is falling a little by mounting of MMIC switch, the averaging gain of the desired direction is improving by about 6dB or more from the other directions. Therefore, PCSYUA is operating as a beam switch antenna. Moreover, the size of PCSYUA with switch is about 30% small compared with the slot Yagi-Uda antenna [3] by share of director and reflector.

4. Conclusion

We proposed beam switched small antenna using slot Yagi-Uda antennas for Wireless LAN The beam direction of this antenna can be changed to quad orthogonal directions by exchanging the role of director and reflector. This antenna is able to miniaturize to about 30% by share of director and reflector.

Reference

[1] K.Uehara, T.Seki, K.Kagoshima, “Indoor Propagation Calculation Considering Antenna Patterns Using Geometrical Optics Method”, IEICE Trans Japan, vol. J78-B-II, no. 9, pp.593-601, Sep 1995.
[2] T.Maruyama, K.Uehara, K.Kagoshima, “Design and Analysis of Small Multi-Sector Antenna for Wireless LANs Made by Monopole Yagi-Uda Array Antenna”, IEICE Trans Japan, vol. J80-B-II, no. 5, pp.424-433, May 1997.
[3] T.Kawamura, M.Yamamoto, T.Hikage, K.Itoh, “A Planar-Type Multi-Sector Antenna Consisting of Slot Yagi-Uda Array”, IEICE Trans Japan, vol. J85, no. 9, pp.1633-1643, Sep 2002.



ML=2, MO=6.1, WS=WD=WR=2, SD=SR=15,
DO=8, LD=18.5, LR=20.5, LG=40 (Unit: [mm])

Fig.1: Structure of PSYUA

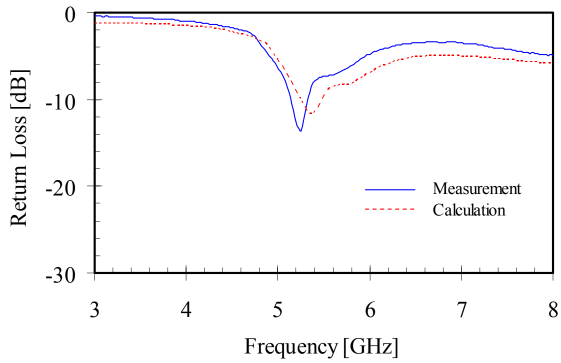
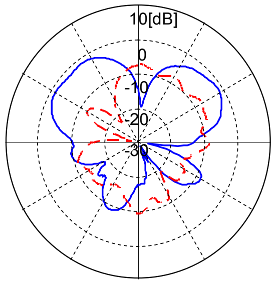
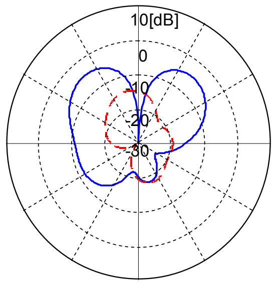


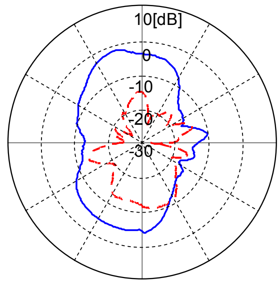
Fig.2: Input characteristic of PSYUA



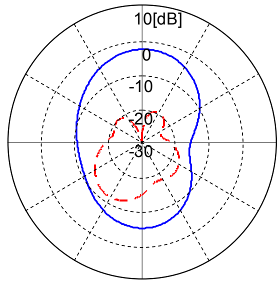
(a)XY-Plane (Measurement)



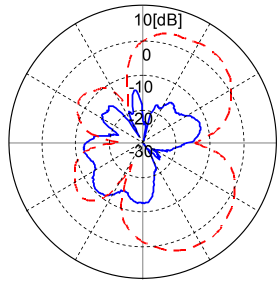
(b)XY-Plane (Calculation)



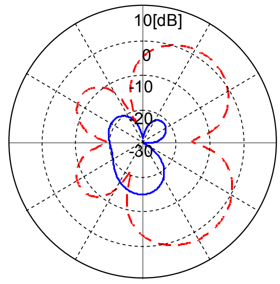
(c)XZ-Plane (Measurement)



(d)XZ-Plane (Calculation)



(e)YZ-Plane (Measurement)



(f)YZ-Plane (Calculation)

Solid: Horizontal Pol. Dotted: Vertical Pol.

Fig.3: Radiation pattern of PSYUA

Table1: Antenna gain of PSYUA (Measurement)

	XY Plane	XY Plane	XY Plane
Max Gain	-1.12	-1.95	4.30
Average Gain	-5.74	-6.94	-0.83

(Unit: [dBi])

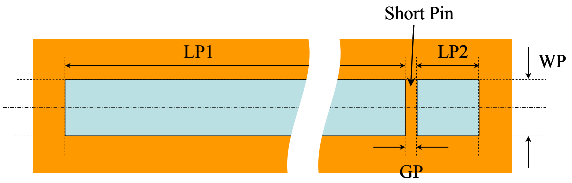
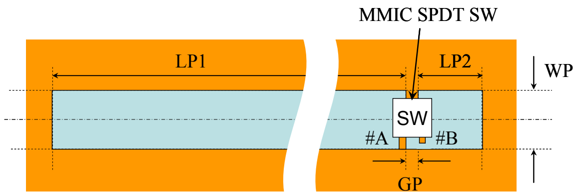
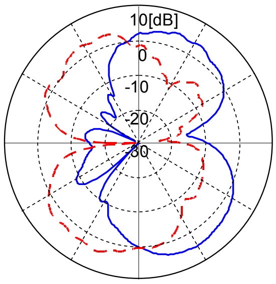


Fig.4: Parasitic Slot

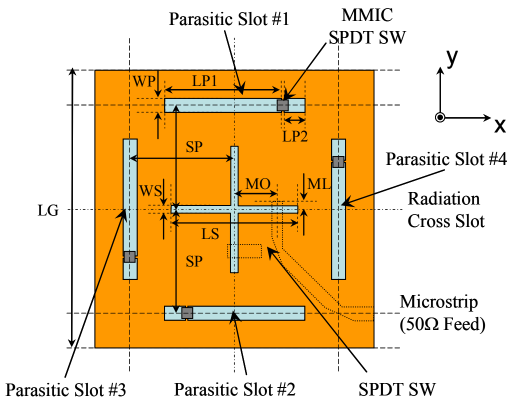


LP1=18.5, LP2=2.0 (Unit: [mm])

Fig.5: Parasitic Slot with SPDT SW



Solid: #1: Open (#B), #2: Short (#A)
Dotted: #1: Short (#A), #2: Open (#B)
ML=2, MO=6.1, WS=WP=2, LS=17, SP=15,
LP1=18.0, LP2=2.0, LG=40 (Unit: [mm])
Fig.6: Radiation pattern of PSYUA with switch



ML=1, MO=6.1, WS=WP=2, LS=18, SP=15, LP1= 18, LP2= 2, LG=40 (Unit: [mm])
Fig.7: Structure of PCSYUA

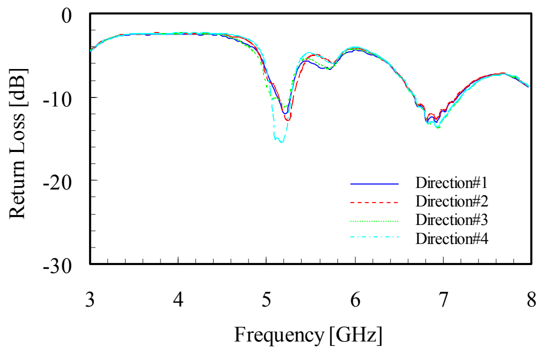
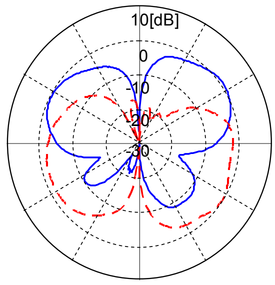
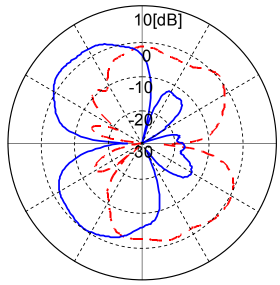


Fig.8: Input characteristic of PCSYUA



(a)XZ-Plane (Measurement)
Solid: Direction#1, Dotted: Direction#2



(b)YZ-Plane (Measurement)
Solid: Direction#3, Dotted: Direction#4
Fig.9: Radiation pattern of PCSYUA with switch

Table2: Antenna gain of PCSYUA with switch

		#1	#2	#3	#4
Max Gain		0.82	-0.09	1.05	2.17
Ave	All	-4.68	-4.51	-3.70	-3.55
	Desired	-1.76	-2.13	-1.04	-0.14
	Others	-10.4	-7.84	-7.06	-12.4

(Unit: [dBi])