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Design of Directivity of Tapered Slot Antenna for Triple-Band Cellular Base Stations

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***Abstract* - In this report, a tapered slot antenna (TSA) for triple-band cellular base stations is proposed. Two pairs of slits are introduced to the TSA to realize desired half-power beamwidth and front to back (F/B) ratio. It is shown that the proposed TSA radiates a sector beam with high F/B ratio over 20 dB at the three frequency bands.**

***Index Terms* — Tapered slot antenna, multiband antennas, base station.**

I. INTRODUCTION

In recent years, mobile communication systems are widely used and more and more services which use different frequency bands have been started. Therefore, multiband base station antennas have much attention. The multiband base station antennas should have desired directivity over all frequency bands, e.g. constant half-power beamwidth and high front to back (F/B) ratio. On the other hand, the size of the base station antenna should be kept because the installation space of the base station antenna is limited due to the size of a radome. Therefore, the design of the multiband base station antennas with desired directivity is difficult because of the size limitation.

Previously, various multiband/wideband antennas have been proposed as the base station antennas. A wideband stacked patch antenna has been proposed [1]. It has been demonstrated that the stacked patch antenna shows $65^\circ \pm 6^\circ$ of half-power beamwidth at 1.7/2.2/2.7 GHz bands while its F/B ratio deteriorates in lower frequency band. On the other hand, antennas which cover 1710-2170 MHz band have been proposed [2] [3]. These antennas show a constant half-power beamwidth and high F/B ratio in the operating frequency band. However, these papers mainly focus on wideband impedance matching but how to design the directivity of these antennas is not clarified in these papers.

In this report, we propose a compact tapered slot antenna (TSA) for an application of 6-sector multiband base station. The directivity of the proposed TSA is designed at 1.5/2/2.4 GHz bands. Two pairs of slits are loaded to the TSA to realize a six sector beam in the frequency bands. Results of numerical simulations show that the designed TSA radiates a sector beam with high F/B ratio over 20dB at the three frequency bands. Moreover, how two pairs of slits enhance the directivity of the TSA is clarified.

II. CONFIGURATION OF THE PROPOSED ANTENNA

Table I shows the desired performance of the proposed antenna. The proposed antenna requires stable radiation pattern (i.e. half-power beamwidth and F/B ratio) at the three frequency bands. The entire size of the antenna is limited by the size of a cylindrical radome.

Fig. 1 shows the configuration of the proposed antenna, which consists of the TSA and a reflector. The TSA has elliptical shape and installation space in the cylindrical radome can be fully utilized. The TSA is backed by the bended reflector. The bended reflector is introduced to enhance the F/B ratio of the TSA.

At both edges of TSA, two pairs of slits are loaded. Because the current distribution on the TSA is controlled by the slits, desired half-power beamwidth and F/B ratio can be realized. The lengths of two pairs of slits are l_{slit1} and l_{slit2}, respectively. The spacings between the reflector and slits are x_{slit1} and x_{slit2}, respectively.

III. ANTENNA DESIGN

The enhancement of the half-power beamwidth and the F/B ratio of the TSA by two pairs of slits is shown. Numerical simulations were performed using FEKO which is a numerical simulator based on the method of moments (MoM).

Fig. 2 shows the effect of the slit length l_{slit2} to the half-power beamwidth of the TSA. It is found that half-power beamwidth of the TSA at each frequency is strongly affected by the slit length l_{slit2}. As can be seen in Fig. 2, Half-power beamwidth of $60^\circ - 70^\circ$ is achieved at all frequency bands when $l_{slit2} = 45$ mm.

Fig. 3 shows the effect of the slit length l_{slit2} to the F/B ratio. It can be seen that F/B ratio at each frequency is affected by l_{slit2}. Moreover, F/B ratio at each frequency tends to increase as the slit length l_{slit2} increases. The F/B ratio over 20 dB is realized at all three frequency bands when the slit length l_{slit2} is greater than 40 mm. As a conclusion, it is found that the TSA realizes half-power beamwidth of $60^\circ - 70^\circ$ and F/B ratio over 20 dB at all frequency bands when the slit length $l_{slit2} = 45$ mm.

TABLE I
DESIRED PERFORMANCE OF THE PROPOSED ANTENNA

Frequency Bands	1.5, 2, 2.4 GHz
Front to Back Ratio	≥ 20dB
Number of Sectors	6
Half-Power Beamwidth (Horizontal Plane)	$60^\circ - 70^\circ$
Size of Radome	ϕ200 mm × 2500 mm

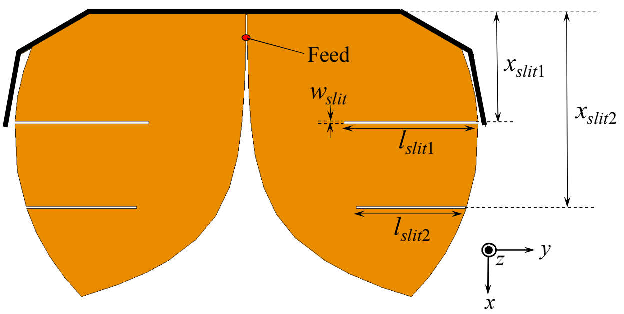

Fig. 1. Configuration of the proposed antenna.

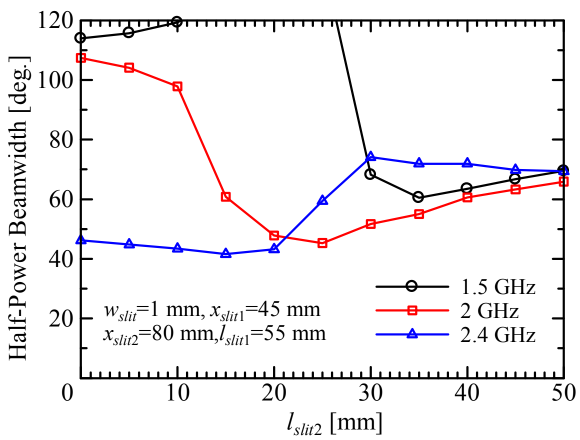

Fig. 2. Effect of slit length l_{slit2} on half-power beamwidth.

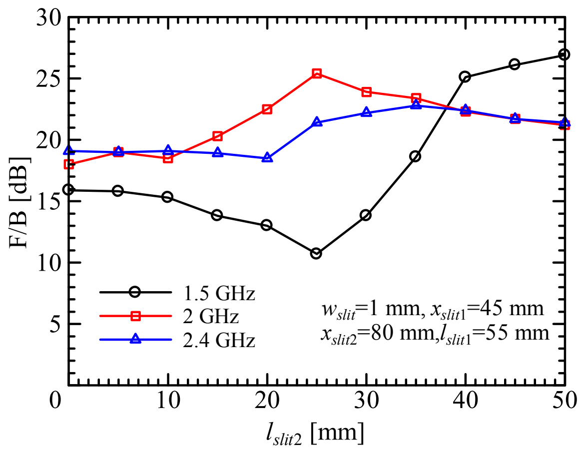

Fig. 3. Effect of slit length l_{slit2} on F/B ratio.

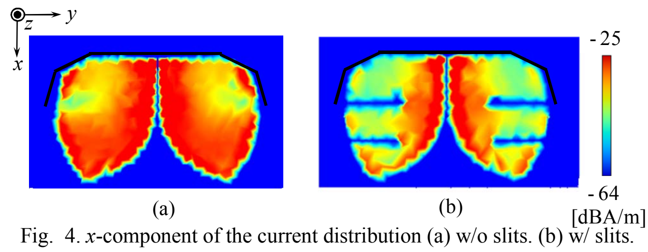

Fig. 4. x-component of the current distribution (a) w/o slits. (b) w/ slits.

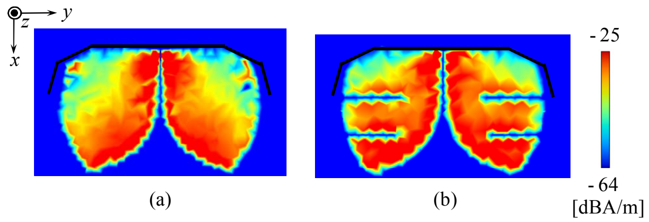

Fig. 5. y-component of the current distribution (a) w/o slits. (b) w/ slits.

Finally, how two pairs of slits affect the directivity of the TSA is discussed from the physical point of view. Fig. 4 and Fig. 5 show the current density distribution of the TSA at 2 GHz. Fig. 4 shows the distribution of the magnitude of the x-component of current density and Fig. 5 shows that of the y-component. It is observed that the x-component of current density on the TSA is partly suppressed by introducing slits while y-component current is partly increased by introducing slits. In general, the x-component of current density on the TSA contributes to radiation in y direction. Therefore, half-power beamwidth of the TSA deteriorates when the x-component of current density on the TSA is strong. By loading the slits which are extended to y-direction, the x-component of current density on the TSA is only suppressed. As a result, the directivity of the TSA with two pairs of slits can be enhanced.

IV. CONCLUSION

In this report, the compact tapered slot antenna for triple-band cellular base station was designed. It is shown that, by introducing slits to the TSA, the half-power beamwidth and F/B ratio of the TSA could be enhanced. The designed TSA showed half-power beamwidth of $60^\circ - 70^\circ$ and F/B ratio over 20 dB at the three frequency bands without violating the size limitation.

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