A Novel Base Station Antenna Based on Rectangular Waveguide

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***Abstract* - A novel base station antenna element is proposed. It consists of a surface of parallel strips to rotate the polarization direction and a segment of a rectangular waveguide. The surface is designed on a single-sided substrate, which has the same area as the aperture of the waveguide. In assembling, the non-copper side of the substrate is placed in direct contact with the aperture of the waveguide antenna. To achieve the polarization rotation, the parallel strips on the surface are rotated by 45° with respect to the walls of the waveguide antenna. By adding the surface, the linear polarization direction of the rectangular waveguide antenna is rotated by 45° to comply with the requirements of cellular industry. SMA connector with a conical probe is used as the coaxial-to-waveguide adaptor. Results have shown that the proposed antenna has a fractional impedance bandwidth of 35%, and a stable radiation pattern is also achieved.**

***Index Terms* — Antennas, base station, waveguide, polarization Rotation.**

1. Introduction

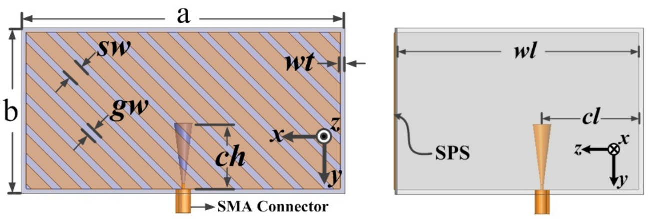
±45° dual-polarized antennas have been widely applied in cellular base stations, as they can enhance the signal reception quality in modern mobile communication systems [1-4]. Currently, the main types of base station antennas include slot and dipole antennas. For a base station, such antennas have the advantage of compact size, mainly because radiators could be easily rotated and placed crosswise, forming a ±45° dual polarized radiation. However, the main drawback of such antennas is their relatively narrow operating frequency band. To widen the band, balun or other structures are needed to improve the impedance matching, as a result, the complexity and cost are both increased. Therefore, base station antennas that cover a wide frequency band with simple and low cost structures are desirable for modern mobile communication systems.

For applications where the required gain is not particularly high, an open-ended waveguide serves as a good antenna. An open-ended rectangular waveguide is linearly polarized and the polarization direction is along the short walls. The advantages of waveguide antennas are moderate directivity, good impedance matching and stable radiation patterns over broad bandwidth, simple construction and adjustment. Note that a broad bandwidth with good impedance matching and stable radiation patterns is what a base station antenna requires [1], however, waveguide antenna is rarely applied into base station, especially for the design of ±45° dual polarized antenna. There are two reasons for this, firstly, two waveguide antennas have to be rotated to radiate ±45° linear polarized wave. Secondly, they cannot be placed crosswise and overlapped in a compact way as the dipole antennas are. Therefore, if the polarization direction of a waveguide antenna could be rotated without rotating the antenna itself, it would be much easier for two of them to be combined in a compact way.

In this paper, a novel method is presented to rotate the polarization direction of a waveguide antenna using surface of parallel strips (SPS). The metallic SPS is designed on a single-sided substrate, which has the same area as the aperture of the waveguide. In assembling, the non-copper side of the substrate is placed in direct contact with the aperture of the waveguide antenna. To achieve the polarization rotation, the parallel strips on the SPS are rotated to make an angle of 45° with the walls of the waveguide antenna. By combining the SPS with the waveguide antenna, the linear polarization direction is rotated by 45 degrees, which is perpendicular to the direction of the strips. The wave guide antenna together with the SPS (WA-SPS) is designed using Ansys HFSS. Simulated results have shown that the operating bandwidth is from 1.65 to 2.35 GHz (35%), where the VSWR < 1.5, Gain = 6.85 ± 0.5 dBi, half power beamwidth (HPBW) in horizontal plane is from 64° to 71°. The results show that the proposed antenna could be a potential candidate for base station application, of which the main advantage is simple construction and adjustment.

2. Designs of Antenna

The waveguide used is a WR510 standard waveguide, of which the dominant propagation mode is TE10 and the co-polarization direction is along y-axis as shown in Fig. 1(a). To make the whole antenna lighter, the material of the waveguide is chosen to be aluminum. The waveguide is fed by a SMA connector as shown in Fig. 1. The pin of the SMA connector is connected to a conical probe to obtain wider impedance bandwidth. The surface of parallel strips (SPS) is printed on a single-sided substrate, which has the same area with that of the waveguide antenna's aperture as shown in Fig. 1(a). In assembling, the non-copper side of the substrate is placed in direct contact with the aperture of the waveguide antenna. The substrate employed in this work is Rogers 5880, which has a thickness of 0.8 mm and a relative permittivity of 2.2. The parallel strips on the SPS are metal and rotated by 45° with respect to x-axis, as shown in Fig. 1(a).



(a) (b)

Fig. 1 Structure of WA-SPS. (a) Top view and (b) side view.

As will be seen later, the polarization direction of the waveguide antenna is rotated with the rotation of the strips on SPS, but in the opposite direction. The waveguide antenna together with SPS here is called WA-SPS for short. The antenna is studied and designed using the EM simulation tool HFSS. The optimized dimensions are listed in TABLE I..

TABLE I

Dimensions of WA-SPS (Unit: mm)

a	*b*	*sw*	*gw*	*wt*	*ch*	*wl*	*cl*
129.54	64.77	6	3	2	25	100	35

3. Results and Discussions

Simulated Voltage Standing Wave Ratio (VSWR) of the proposed antenna is shown in Fig. 2. It is observed that the VSWR is lower than 1.5 in the band from 1.65 to 2.35 GHz, with a fractional bandwidhth of 35%. Due to the structural symetry of the antenna, only VSWR of Port1 is shown here, the same below.

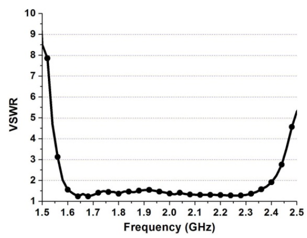


Fig. 2. VSWR.

The E-filed distributions on the aperture of the waveguide antenna without and with SPS are shown in Fig. 3. It is observed from the figure that by using the SPS, the polarization direction is rotated by 45° and perpendicular to the direction of the strips. Due to the strong electromagnetic coupling between the waveguide and the SPS, current distribution occurs along the strips, as a result, 45° linearly polarized wave is radiated from the SPS.

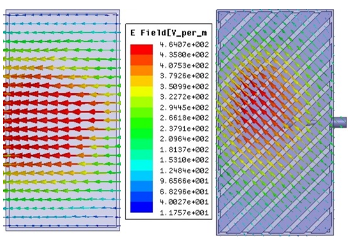


Fig. 3 E-filed distribution on the apertue of waveguide with (right) and without (left) SPS.

Radiation patterns at the *xz*-plane are shown in Fig. 4. To be more specific, TABLE II lists the summary of radiation characteristics when Port1 is excited. In the frequency band of 1.65-2.35 GHz, the cross polarization isolation (XPI) is higher than 9.5 dB within the half power beamwidth (HPBW) of the main lobe, stable HPBW is also achieved.

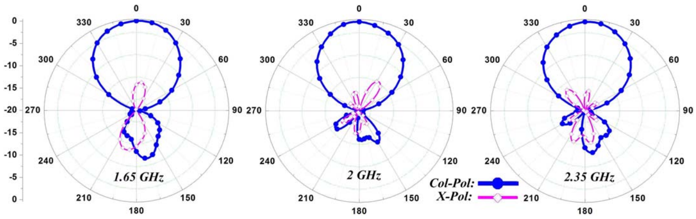


Fig. 3 Radiation patterns

TABLE II

Summary of Radiation Characteristics (Port 1)

Frequency (GHz)	Gain (dBi)	HPBW (°)	XPI	
			Boresight (dB)	Minimum value in HPBW (dB)
1.65	7	66	15.1	9.5
1.8	6.8	69	16.4	12
2.0	6.75	69	16.6	15.5
2.2	7.25	65	20.1	10.1
2.35	6.7	71	18.5	11

4. Conclusion

The design of a ±45° dual-polarized waveguide antenna using surface of parallel strips (SPS) is presented. The final operating frequency band of the proposed antenna is from 1.65 to 2.35 GHz, with a fractional bandwidth of 35%. In the working band, the VSWR is lower than 1.5, the half power beamwidth (HPBW) is 67°±5°, and the boresight gain is 6.85±0.5 dBi. The cross polarization isolation (XPI) is more than 15 dB at the boresight and more than 9.5 dB within the HPBW. Results have shown that the proposed antenna could be a potential candidate for base station application as an element of a ±45° dual polarized antenna.

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