Linear high-gain bidirectional slot array fabricated by narrow bent metallic line

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A linear high-gain slot array with bidirectional broadside radiation is proposed. By utilising a novel slot-energising approach, the slot array obtains a simple and compact geometry, which could be fabricated by a narrow bent metallic line. The slot array achieves an approximately constant magnitude distribution on a long radiating aperture by adopting proper slot elements arrangement and optimising the dimensions. Thus, compared to the existing bidirectional slot arrays in the open literature, the proposed slot array generates a higher gain and moderate gain-to-length ratio. To confirm the build strategy, a prototype with the length of 6.3 wavelength at the centre frequency of 2.4 GHz is constructed, fabricated, and tested, which realises a high gain of 14.0 dBi. With the merits of small size, high gain, low cost, and high-power capacity, the proposed slot array is an attractive substitute for various long-distance communication systems.

Introduction: Owing to the growing demands of the long-distance wireless applications such as wireless sensors networks, microcellular base stations, and bridge or tunnel communication systems, significant attentions have been dedicated to the linear high-gain bidirectional array. Compared to the elements of patches [1], rings [2], cavities [3], and open-end waveguides [4], slots have inherent bidirectional radiation with a simpler geometry [5]. Consequently, slot elements have been extensively utilised in bidirectional arrays. On the basis of slot elements, a linear high-gain bidirectional array could be constructed by two typical means. One of the methods is to arrange the slot elements periodically in a line configuration and energise the elements by a feed network. However, influenced by the feed network, the slot arrays might suffer from large dimension, multi-layer substrates, and high radiation loss. The other method is to realise a series-fed linear slot array [6–10], which integrates the slot elements and feed line into a miniaturised linear array. Nevertheless, according to the series-fed designs in the open literature, impendence transformer lines are usually required to achieve reasonable match [6–8] or the long sides of the slot elements are perpendicular to the feed line to obtain appropriately exciting [9, 10]. Thereby, the designs [6–10] are with necessary large ground planes, which lead to comparatively bulky configurations.

To achieve a more compact linear high-gain bidirectional slot array, a novel slot-exciting approach is proposed, which could make the long sides of the slots parallel to the guiding direction to reduce the width of the array. With an optimised structure, which is manufactured by bending a narrow metallic line, the slot array generates high-gain bidirectional beams with the advantages of compact, low-cost, easy fabrication, and high-power capacity. In the following sections, the slot-energising method and operating principle of the slot array are demonstrated, and a prototype is realised to verify the design strategy.

Configuration and operation mechanism: As depicted in Fig. 1, by bending a narrow metallic line which is cut with multiple slots, the slot array could be readily realised. The detailed structure of the slot array is plotted in Fig. 2. The feed line of the slot array is a short-end parallel strip line. Owing to the low thickness H, the parallel strip line has a very weak radiation capability. A coaxial line is employed to excite the parallel strip line. To reduce the influence of the discontinuity, a taper is added between the parallel strip line and the coaxial line. By alternately notching the slots on the top and bottom layers of the parallel strip line, the energy in the parallel strip line could be effectively radiated to free space. In the design process, the centre frequency of the slot array is mainly determined by the length S_L of the slots, and the width S_W and distance D of the slots affect the aperture distribution and operating bandwidth.

The working principle of the slot-energising method is shown in Fig. 3. Owing to the edge effect, the parallel strip line has a higher electric current magnitude on the side. By placing the slots close to the side, the slots could be energised by the asymmetrical electric current. The vector electric field distributions of the slots on the different layers of the parallel strip line in the same moment are presented in Fig. 4. Owing to the same magnitude and opposite direction, the slot array achieves a bidirectional radiation pattern with nulls along the X-axis.

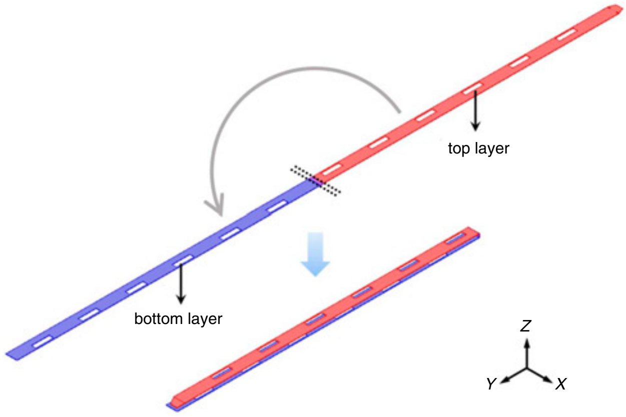

Fig. 1 *Manufacturing procedure of proposed slot array*

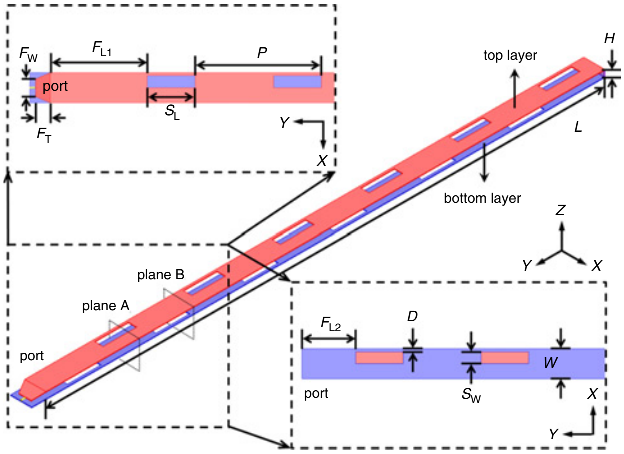

Fig. 2 *Geometry of proposed slot array*

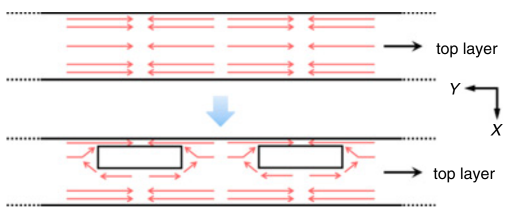

Fig. 3 *Schematic vector electric current field distributions on top layer of proposed slot array with or without slot elements*

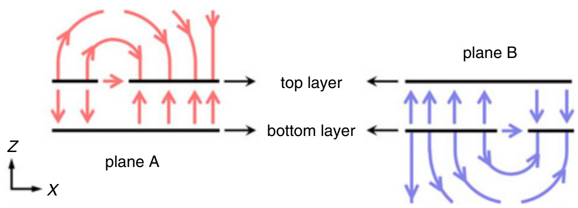

Fig. 4 *Schematic vector electric field distributions of proposed slot array on planes A and B (planes A and B are plotted in Fig. 2)*

Experimental results: A prototype is fabricated and measured to prove the feasibility of the design strategy, as depicted in Fig. 5. An 8-mm-thick foam is added within the slot array as the support. Fig. 6 shows that the measured beamwidths of the radiation pattern on E-plane and H-plane are 65° and 9.5°, respectively. From Fig. 6, it is noted that the slot array is with low sidelobe, which is lower than −12 dB, and high cross-polarisation discrimination, which is higher than 13 dB. According to Fig. 7, the measured operating bandwidth ($|S_{11}| < -10$ dB) is 62 MHz. At the frequency of 2.39 GHz, the slot array achieves a maximum measured gain of 14.1 dBi with high efficiency of 95%.

Fig. 5 *Photograph of proposed slot array*

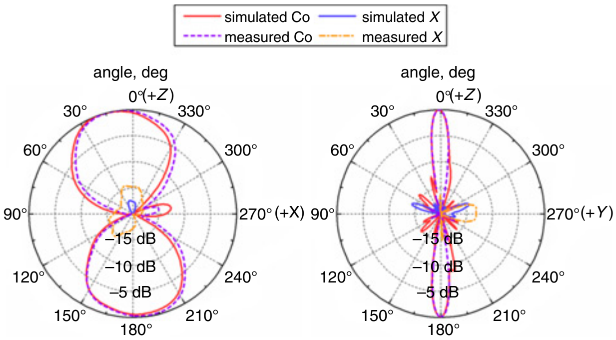

Fig. 6 *Simulated and measured normalised radiation patterns on E-plane (XOZ-plane) and H-plane (YOZ) of proposed slot array at centre frequency of 2.4 GHz*

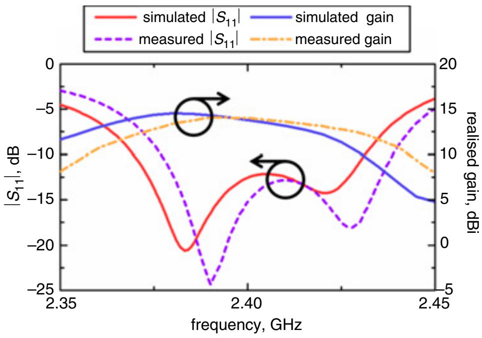

Fig. 7 *Simulated and measured reflection coefficients and peak gains of proposed slot array*

As exhibited in Tables 1 and 2, compared to the antennas with the same design purposes, the proposed slot array has a narrower width even though the array is with air media. Furthermore, because of the longer radiating aperture and relatively uniform aperture distribution, the proposed slot array obtains a higher gain and reasonable gain-to-length ratio (G/L).

Table 1: Detailed configuration of proposed slot array

Parameter	L	W	H	P	S_L	S_W
Value (mm)	787	30	8	125	47.5	12

Parameter	D	F_{L1}	F_{L2}	F_W	F_T
Value (mm)	3	95.5	53	17.5	14.5

Table 2: Comparison of configurations and gains

Ref.	ε_r	f_0 (GHz)	$L \times W \times H$ $(\lambda_0 \times \lambda_0 \times \lambda_0)$	Gain (dBi)	G/L
[6]	4.30	5.40	2.06 × 1.08 × 0.03	9.0	3.86
[7]	4.30	5.50	3.06 × 0.59 × 0.01	11.0	4.11
[8]	2.55	2.45	4.00 × 0.80 × 0.01	11.1	3.22
[10]	4.40	2.40	1.52 × 0.76 × 0.01	6.7	3.08
Ours	1.00	2.40	6.30 × 0.24 × 0.06	14.0	3.99

Conclusion: In this Letter, a novel linear high-gain bidirectional slot array is proposed. It uses a novel slot-exciting approach, which is reported for the first time to the best of our knowledge. A fabricated prototype is realised, and the experimental results show that the slot array could generate a high-gain bidirectional radiation pattern with an all-metal and compact configuration. With the merits of compact, low cost, easy fabrication, and high-power capacity, the slot array is an attractive substitute for the long-distance communication systems, where the bidirectional pattern is required.

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One or more of the Figures in this Letter are available in colour online.

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