# Single-layer waveguide slot array antenna with diaphragms

Y. Oh, J.-H. Hwang and J. Choi

A single-layer waveguide slot array antenna of low cost and high performance for a millimetre-wave wireless communication system at 38 GHz frequency band is presented. The waveguide slots and diaphragms are located together on the cover plate of the antenna, which makes the antenna cost effective and highly efficient. Measurements show a cross-polarisation level below −26 dB and an efficiency level of 86% at the designed frequency.

*Introduction:* A waveguide slot array antenna is a promising candidate for high-gain flat antennas in a fixed wireless access (FWA) system or a local multipoint communication service (LMCS) at 38 GHz band due to its unique features such as lower loss than microstrip antennas and simpler structure than reflector antennas. A serial feeder system with waveguide $\pi$- or/and T-junctions can be connected with the radiating waveguides for millimetre waves in a single layer [1, 2]. The single-layer waveguide slot array antenna usually consists of a slotted plate (e.g. a thin stainless-steel plate) and a base plate with corrugations for waveguides (e.g. a thick aluminium plate). Welding between those plates is necessary for good electrical contact because mechanical contact is not sufficient in this case [1]. To avoid the welding, an alternating-phase fed array antenna has been introduced, for which electrical contact can be dispensed with in principle because the currents on separating walls do not flow across the contacting surface [2]. However, the alternating-phase fed array antenna degrades the antenna gain due to grating lobes by symmetrical slot arrangements with respect to separating walls. Otherwise, we would suffer from either the antenna beam tilting or power loss, to avoid the gain reduction [1].

In this Letter, we propose a cost-effective single-layer waveguide slot array antenna, in which the slots and the waveguides are located together on the upper plate as shown in Figs. 1*a* and *b*. Inductive diaphragms are added in the radiating waveguides to minimise the antenna return loss. A waveguide slot 16 × 16 array antenna with the inductive diaphragms at 38 GHz band has been simulated using a high-frequency structure simulator (HFSS) for optimum performance. The waveguide slot array antenna is manufactured using a computer-controlled milling technique and measured. A good agreement between simulation and measurement is demonstrated.

*Design:* At first, we examined the return loss of a single longitudinal slot on a broad wall of a rectangular waveguide with a terminated short at a quarter-wavelength beyond the slot. The slot width for optimum resonance characteristics is usually too small (e.g. 0.1 mm in this case) to use the milling technique. We added a pair of symmetrical inductive diaphragms near the slot for the best return loss characteristics while keeping the slot width large enough for easy milling (e.g., $w_s = 1.4$ mm in this case).

Then, we designed an array of 16 × 1 waveguide longitudinal slots at 38 GHz band by optimising the positions and sizes of the diaphragms. The array of 16 × 1 slots was fine-tuned to give a −20 dB sidelobe-level Chebyshev array pattern, by controlling the sizes and positions of the diaphragms to satisfy the array amplitude coefficients using

$$P_{rad}/P_{in} = 1 - S_{11}^2 - S_{21}^2$$

The 1 × 16 power divider with a T-junction and eight $\pi$-junctions on a single layer in Fig. 1*b* was designed to have a −20 dB sidelobe-level Chebyshev power distribution. The sizes and positions of the coupling window and inductive walls of each $\pi$-junction are optimised for the Chebyshev power distribution. The input port could be located at the centre using a T-junction. An inductive thin post was inserted at the centre of the T-junction to improve the impedance matching characteristics [3]. Finally, a waveguide slot 16 × 16 array antenna with diaphragms was designed for minimum reflection and optimum radiation characteristics at 38 GHz band.

*Results:* The slot array antenna shown in Fig. 1 was manufactured with aluminium plates using a computer-controlled milling technique. The slot array antenna consists of two plates: an upper waveguide plate with slots and diaphragms and a lower flat plate. The total area of the slot array antenna is 137 × 120 mm, including 10 mm-wide extra peripheral spaces for fastening both plates together with bolts to get a good electrical contact.

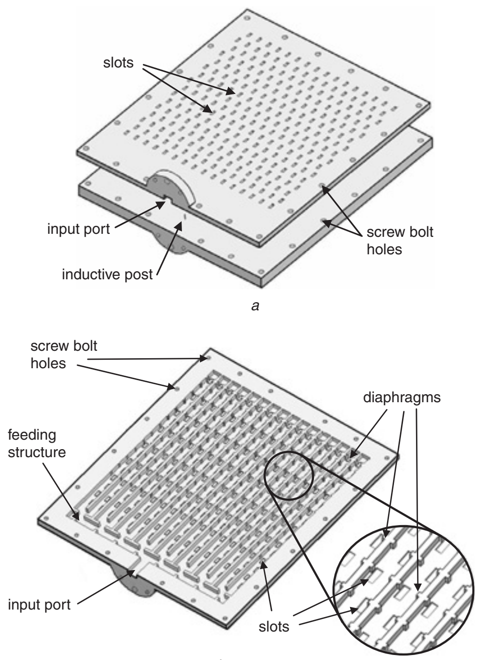


**Fig. 1** *Geometry of single-layer array antenna*

*a* Structure
*b* Inside view of flipped upper plate

Fig. 2 shows the measured return loss of the slot array antenna in the frequency range of 37.6 GHz < $f$ < 38.4 GHz. The measured return loss at 38 GHz is 31 dB, and the bandwidth for $|S_{11}| < -10$ dB (VSWR ≤ 2) is more than 800 MHz.

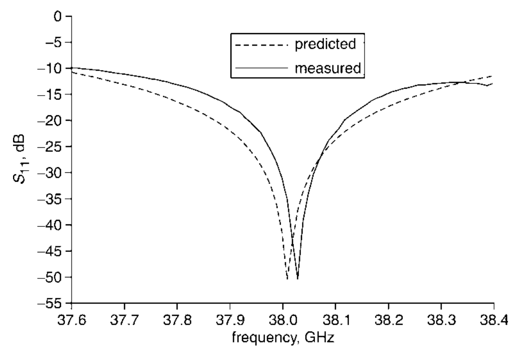


**Fig. 2** *Measured* $|S_{11}|$ *of 16 × 16 waveguide slot array antenna*

The efficiency of the antenna was measured using the Wheeler cap method [4, 5]. At first, the return loss without cap, $S_{11FS}$, and the return loss with cap, $S_{11WC}$, are measured, and then the efficiency is computed using the following equation:

$$\eta_{(Efficiency)} = \sqrt{(1 - |S_{11FS}|^2)(|S_{11WC}|^2 - |S_{11FS}|^2)} \qquad (1)$$

The measured efficiency at 38 GHz is about 86%, as shown in Fig. 3.

Figs. 4*a* and *b* show comparisons between the simulated and the measured antenna patterns on the principal E- and H-planes. The measured antenna patterns agree quite well with the simulated results. The half-power beam widths (HPBW) of the E- and H-plane patterns are 4.8 and 5.6°. The relative power levels of the first sidelobes for E- and H-plane patterns are approximately −19.6 and −18.5 dB, respectively, and all other sidelobe levels are below −20 dB, as shown in Fig. 4. The cross-polarisation levels are below 26 dB in both radiation patterns, as shown in Fig. 4. The measured gain is 31.2 dBi, which agrees well with the simulated gain of 30.6 dBi.

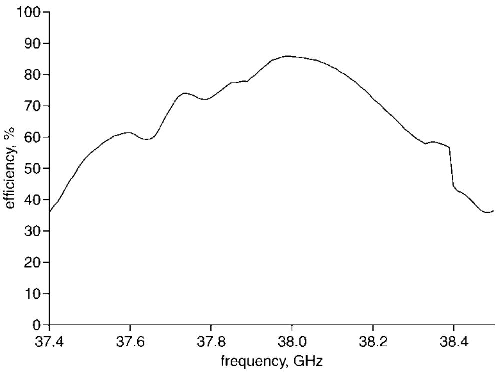


**Fig. 3** *Measured efficiency of 16 × 16 waveguide slot array antenna*

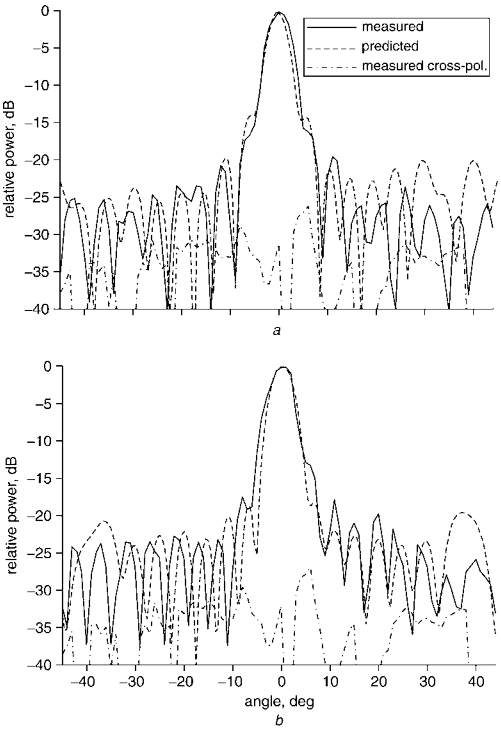


**Fig. 4** *Comparison between predicted and measured antenna patterns*

*a* E-plane patterns
*b* H-plane patterns

*Conclusions:* We propose a single-layer waveguide slot array antenna, in which the slots and the waveguides are located on the same plate without separation, which alleviates the necessity of welding between the two plates. Inductive diaphragms near slots at the radiating waveguides allowed easy milling and high performance of the antenna. The measured and the simulated results agree with each other very well. The antenna showed a gain of 31.2 dBi and sidelobe levels below −18 dB with 16 × 16 arrays. The antenna also shows a cross-polarisation level below −26 dB and an efficiency level of 86% at the designed frequency. The proposed antenna will be practical in view of manufacturing cost and performance level.

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