The Wide-band Two-element Microstrip Slot Array Antenna with the Cross-shaped Feedline

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Abstract

The design, numerical simulation, and an experimental implementation of two-element cross-shaped microstrip line-fed printed slot array antenna for IMT-2000 at the 2.0 GHz band is presented in this paper. The proposed antenna with relative permittivity 4.3 and thickness 1.0mm is analyzed by the Finite-Difference Time-Domain (FDTD) method. It was shown that the measured 2.0 VSWR bandwidth of one-element microstrip slot antenna is from 1.42 GHz to 2.69 GHz, which is approximately 61.8% and that of two-element microstrip slot array antenna is from 1.42 GHz to 2.56 GHz, which is approximately 57.3%. And it was shown that the measured gain of one-element microstrip slot antenna is 2.75 dBi and that of two-element microstrip slot antenna is 4.75 dBi. The antennas were fabricated and tested. The measured results are in good agreements with the FDTD results.

1. Introduction

It is requirements for microwave equipments to have low profile and light weight antennas to assure a reliability. The antenna which has been researched according to these requirements is a microstrip antenna. Microstrip antennas have the advantages of their conformal structure, low cost, and ease of fabrication and integration with solid-state devices as well as low profile and light weight. However, microstrip antennas have the disadvantage of the limitation of their bandwidth which is about 1-2%. In the last decade, a great deal of research has been devoted to the bandwidth widening technique of microstrip antennas [1]. A popular method is the use of parasitic patches, either in another layer (stacked geometry) or in the same layer (coplanar geometry). However, the stacked geometry has the disadvantage of increasing the thickness of the antenna, and the coplanar geometry has the disadvantage of increasing the lateral size of the antenna [2].

In this paper, the broadband microstrip slot antenna is investigated [3]. Numerical results developed by the FDTD code are presented in the second section. In the third section, experimental results are presented. Finally we conclude with a summarization of our finding and applications.

2. The design of antenna

The geometries of one-element and two-element microstrip slot array antennas are shown in Fig. 1. These antennas are designed by adding three open stubs to microstrip line. The relative permittivity of the substrate is 4.3 and the thickness of the substrate is 1.0 mm. In Fig. 1, L_s is the slot length, W_s is the slot width, L_d is the horizontal component length, L_u is the upper side length of cross-shaped feed-line, W_f is the width of feed-line, and offset is the interval length of slot center and horizontal component feed-line center. To analyze the antenna correctly, Δx and Δy are chosen so that an integral number of nodes fit the feed-line and slot exactly. Δz are chosen so that an integral number of nodes fit the thickness h of the substrate exactly.

The spatial step sizes used are $\Delta x = 0.97$ mm, $\Delta y = 1.0$ mm and $\Delta z = 1.0$ mm. The thickness of substrate (h) is $1\Delta z$, the length of slot (L_s) is $65\Delta x$, the width of slot (W_s) is $32\Delta y$, the length of horizontal component feed-line (L_d) is $31\Delta x$, the length of upper side vertical feed-line (L_u) is $10\Delta y$, and the offset length of horizontal component feed-line center interval from slot center is $8\Delta y$. To calculate the far-field pattern, 10 free space mesh cells are added to the top and bottom of substrate. The total mesh dimensions of one-element antenna are $148\Delta x \times 112\Delta y \times 21\Delta z$ and those of two-element antenna are $246\Delta x \times 121\Delta y \times 21\Delta z$. The time step is 1.9 ps. The Gaussian pulse is excited just underneath the dielectric interface of antenna. The pulse width is 32 time steps.

Fig. 2 shows the comparison of calculated VSWR of one-element and two-element microstrip slot antenna. The usable frequency below 2.0 VSWR of one-element microstrip slot antenna is from 1.48 GHz to 2.54 GHz and the bandwidth is 1.06 GHz. The usable frequency below 2.0 VSWR of two-element microstrip slot antenna is from 1.42 GHz to 2.74 GHz and the bandwidth is 1.32 GHz. According to Fig. 2, the bandwidth of two-element microstrip slot array antenna is 0.26 GHz larger than one-element microstrip slot antenna.

Fig. 3 shows the calculated VSWR of two-element microstrip slot array antenna as a function of the horizontal component feed-line length (L_d). In Fig. 3, other parameters except for the horizontal component feed-line length (L_d) are also setted to the fundamental value. The bandwidth is about 1.07 GHz for L_d of 35 mm, 1.08 GHz for L_d of 31 mm, and 1.05 GHz for L_d of 27 mm. So when L_d is 31 mm, the bandwidth becomes a maximum.

Fig. 4 shows the $E_z(y,z,t)$ distribution of two-element microstrip slot array antenna just underneath the dielectric interface at 1000 time steps.

3. Experiment results

The antennas were fabricated and tested by using FR-4 substrate. The ground plane size of one-element microstrip slot antenna is 143 mm × 112 mm, and that of two-element microstrip slot array antenna is 239 mm × 121 mm. The return loss of the antenna was measured with an HP-35181E network analyzer.

Fig. 5 and Fig. 6 shows the measured VSWR of one-element and two-element microstrip slot antennas. It can be seen that the 2.0 VSWR bandwidth of one-element antenna is from 1.42 GHz to 2.69 GHz, which is approximately 61.8%. That of two-element array antenna is from 1.42 GHz to 2.56 GHz, which is approximately 57.3%.

Fig. 7 and Fig. 8 shows the measured E-plane radiation pattern of one-element and two-element microstrip slot array antennas for the center frequency 2.0 GHz. The measured half-power beamwidths of one-element and two-element microstrip slot array antennas are about 66° and 45°, respectively.

Table. 1 shows the calculated and measured performance of one-element and two-element microstrip slot array antennas. We can know that the 2.0 VSWR bandwidth of two-element microstrip slot array antenna is 4.5% smaller than that of one-element microstrip slot antenna, but the gain of two-element microstrip slot array antenna is 2.0 dBi larger than that of one-element microstrip slot antenna.

4. Conclusions

In this paper, the calculated results of a wide-band microstrip antenna using the FDTD method have been presented. The antennas with a maximum bandwidth were fabricated and tested. The measured 2.0 VSWR bandwidth of one-element microstrip slot antenna is from 1.42 GHz to 2.69 GHz, which is approximately 61.8%. And that of two-element microstrip slot antenna is from 1.42 GHz to 2.56 GHz, which is approximately 57.3%. The measured –3 dB beamwidths of one-element and two-element microstrip slot array antennas are approximately 66° and 45°, respectively. Actually in Table. 1, we can also see that the gain of a two-element microstrip slot array antenna is larger than that of a one-element microstrip slot antenna.

Since this antenna has the advantage of wide-bandwidth, low cost, ease of fabrication, and integration with solid-state devices as well as low profile and light weight, it may find proper applications in IMT-2000, mobile communications, satellite communication, wide-band communication system, and so on.

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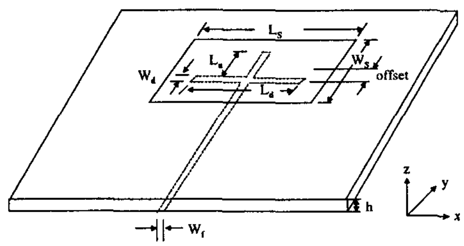
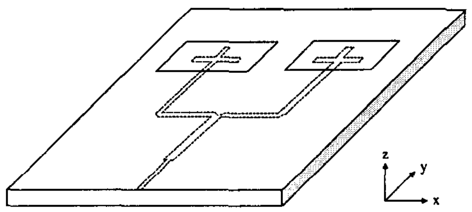


(a)



(b)

Fig. 1. (a) Geometry and design parameters of one-element microstrip slot antenna (b) Geometry and design parameters of two-element microstrip slot array antenna

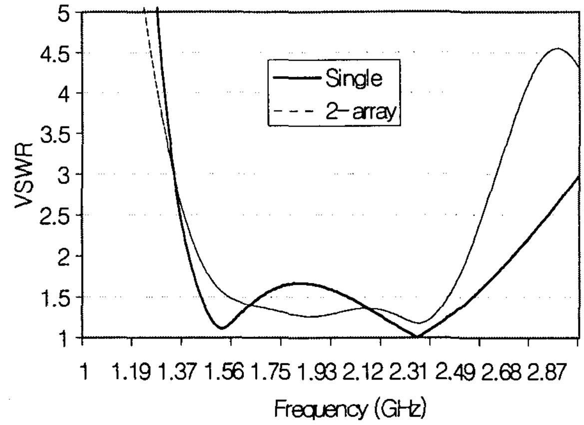


Fig. 2. Comparison of calculated values between VSWR of one-element and two-element microstrip slot antennas.

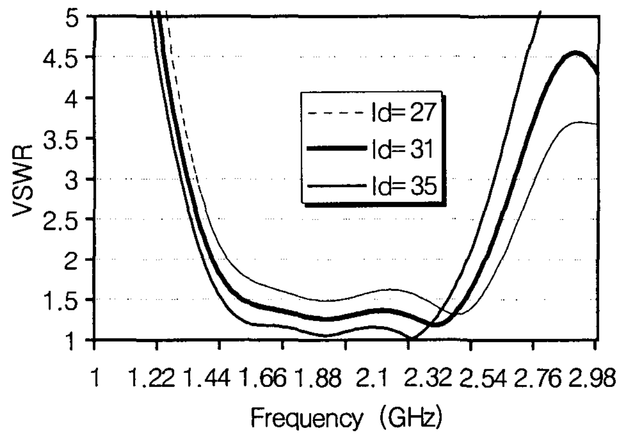


Fig. 3. Calculated VSWR of two-elements microstrip slot array antenna as a function of horizontal component feed-line length (l_d).

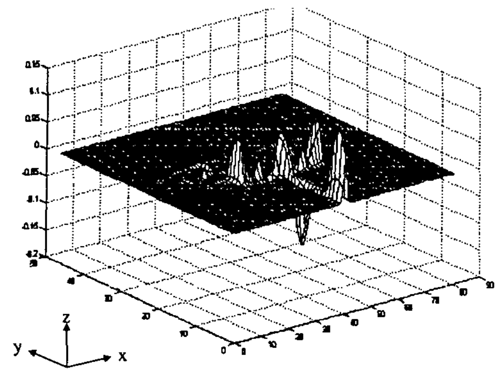


Fig. 4. $E_z(x,y,t)$ distribution of two-element microstrip slot array antenna just underneath the dielectric interface at 1000 time steps (sampling rate = 3).

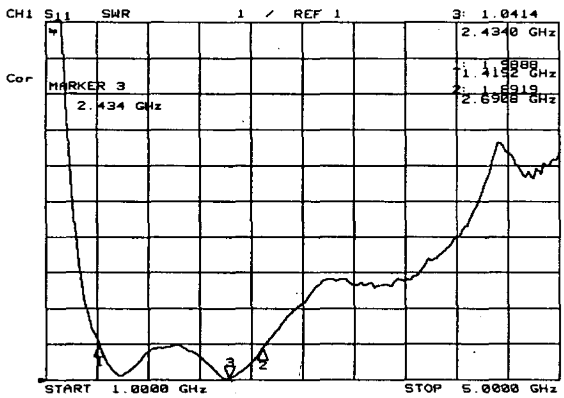


Fig. 5. Measured VSWR of one-element microstrip slot antenna

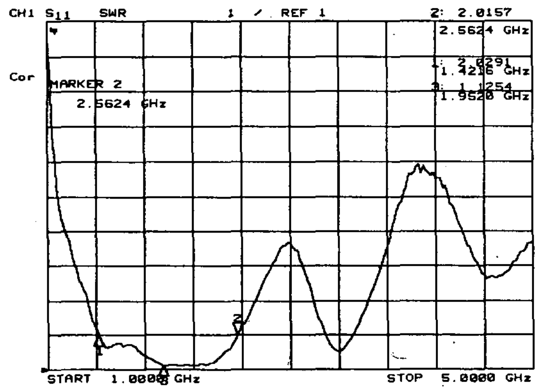


Fig. 6. Measured VSWR of two-element microstrip slot array antenna.

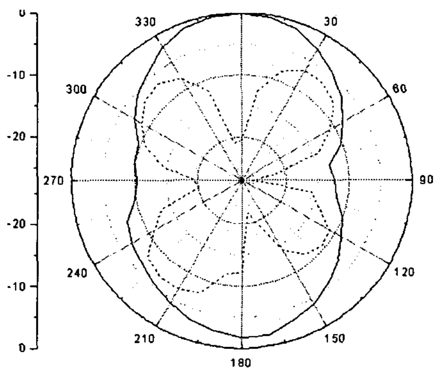


Fig. 7. Measured E-plane radiation pattern of one-element microstrip slot antenna

——— : co-polarization, ··········· : cross-polarization

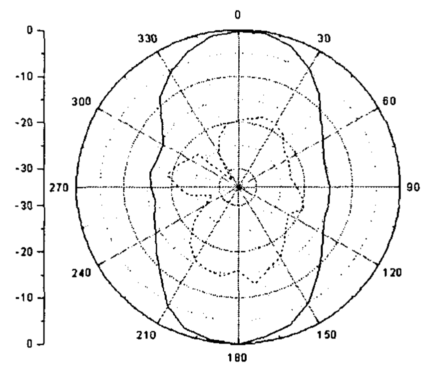


Fig. 8. Measured E-plane radiation pattern of two-element microstrip slot antenna

——— : co-polarization, ··········· : cross-polarization

Table 1. Performance comparison of one-element and two-element microstrip slot array antennas.

The type of antenna	Frequency (GHz)		BW (%)		Gain (dBi)	
	Cal	Mea	Cal	Mea	Cal	Mea
One-element	1.48 ~ 2.54	1.42 ~ 2.69	52.7	61.8	2.57	2.75
Two-element	1.42 ~ 2.74	1.42 ~ 2.56	63.5	57.3	4.60	4.75

* Cal : Calculated, Mea : Measured