

Design of A Single-Layer Waveguide Slot Array Antenna

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Abstract — In this paper, a single-layer millimeter-wave waveguide slot array antenna is presented. The sidelobe is suppressed below 20dBc by using the waveguide feed network with the Chebyshev distribution. With the advantages of the combination with the machining and PCB processing, the BW for VSWR below 1.5 is more than 500MHz, and the gain is 27.9dBi. The low thickness and small volume single-layer waveguide slot array antenna is low cost, and widely using in the system with size limited and high performance requirements.

Index Terms — Waveguide slot, Array antenna, Single-Layer, Low side lobe

I. INTRODUCTION

Nowadays, the electromagnetic environment in the air is more compact and more complex by the great advance of both the sensibility of the receiver and the power of the transmitter. Waveguide slot array antenna has been used widely in airborne fire control radar and microwave communication systems because of their flat, compact structure, power capacity, realizing low side lobe and very low side lobe. The theory research and engineering design of the waveguide slot array antenna developed fast because of the development of the computer technology, the advance of the processing technology of the antenna, and the stimulation of the requirement by the advance of the anti-interference radar and the pulse Doppler radar.

As the result of the widely application of the waveguide slot array antenna, the level of its theory and design increase greatly [1]. By using the distribution function of the digital filter, the array structure of the antenna has been analysed and researched. This method combines the frequency domain and the space domain, and provides a new way for the research of the array antenna [2]. In addition to the design method of the millimeter-wave waveguide slot array antenna, the processing and the testing method of the antenna is researched. The structure of the slot array antenna consists of two layers of waveguides. The slot array of the downlayer waveguide is used for the feed network of the array of the uplayer. By using the structure of slot array of Chebyshev distribution, a -20dB side lobe level was given [3].

However, the slot array antenna with double layers structure requires higher accuracy of the processing technology. And the volume is large for the large thickness because of the multi-layers. So, a novel single-layer structure waveguide antenna is presented [4~6]. The feed network directly consists of waveguide power distribution structure. The slots and the diaphragms are located together in each waveguide

unit to get the better return loss characteristics and reduce the influence of the error of the processing.

In this paper, we propose a single-layer waveguide slot array. By the research of the structure of the waveguide feed network, a Chebyshev power distribution is given. Thus an array antenna with the low side lobe, high efficiency and high gain is realized. At the same time, the slot array plate is manufactured by taking full advantage of the higher accuracy and lower cost processing technology of PCB instead of the machining processing technology. A waveguide slot 18×8 array antenna at 35.5GHz has been simulated for optimum performance and manufactured. And a good agreement between the simulation and the measurement is demonstrated.

II. DESIGN

The waveguide slot array antenna shown in Fig. 1 was consisted of two plates, which frequency is 35.5GHz. The distance between each slot on y axis should be no longer than $\lambda_g/2$.

$$\lambda_g = \frac{\lambda}{\sqrt{1 - (\lambda/2a)^2}} \quad (1)$$

λ_g is the waveguide wave length, λ is the operating wave length, a is the length of the wide side of the internal wall of the waveguide. So, $a \leq \lambda_g/2$. By considering the relationship between the λ_g and a , the value was chosen, $a = 5.4\text{mm}$, $b = 2.7\text{mm}$. And λ_g was calculated. $\lambda_g = 13.57\text{mm}$.

According to the theory of the waveguide slot array antenna, the minimum distance between the short circuit and the last slot is $\lambda_g/4$ in each waveguide, and the distance between each slot on x axis is $\lambda_g/2$. For getting the lower side lobe on the direction of $\phi = 90^\circ$, the antenna normally consists of at least two layers of waveguide. One for radiating slot array, and another for feed slot array. Both of the slot arrays use some distribution method to realize the lower side lobe.

However, if the power distribution feed network of the single-layer array antenna is equally distribution structure as shown in Fig.2(a), the power which was distributed of each branch is shown in Fig.3(a). This structure which would only give a -16dB side lobe level of the direction when $\phi=90^\circ$ couldn't meet the application requirements. For the above problem, the diaphragms are located on the feed network, while the power distribution of the 8 branches are complied with the Chebyshev distribution by the design of the

structure as shown in Fig.3(b). Thus the side lobe characteristics of the single-layer antenna when $\phi=90^\circ$ would be improved as shown in Fig.4. And the thickness of the whole antenna would be reduced observably.

Normally, both the waveguides and the slots of the waveguide slot array antenna are manufactured by the machining processing technology. The whole structure is metal. But because of the limited by the accuracy of the machining processing technology, the width of the slot unit couldn't be narrow enough to ensure the implementation of the performance. So Just only the waveguide array plate is manufactured by the machining processing technology, and the slot array plate is manufactured by the processing technology of PCB using the material of Rogers RT/duroid 5880 with double-sided copper foil. Add the slots array plate on the waveguides array plates would get the waveguide slot array antenna. For the material of the slot array plate is soft, so there is no gap or slot between the two plate and no power leaks. The size of the whole antenna is $145\text{mm} \times 66\text{mm} \times 10\text{mm}$.

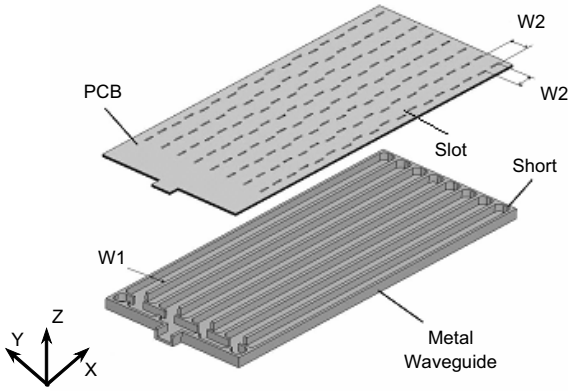


Fig.1 Structure of single layer array antenna
 $W1 = 5.4\text{mm}$, $W2 = \lambda_g/2 = 6.785\text{mm}$

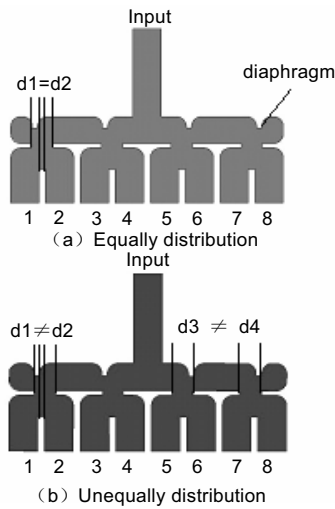
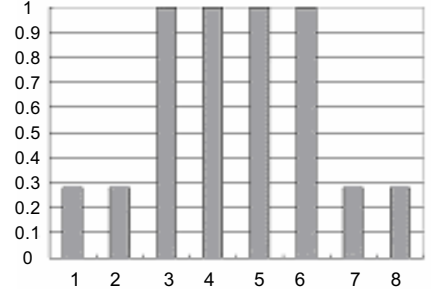
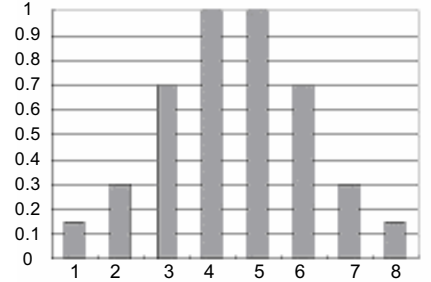


Fig.2 Structure of feed network



(a) Normalized values assigned by equally power distribution structure



(b) Normalized values assigned by Chebyshev power distribution structure

Fig.3 Feed network power distribution value

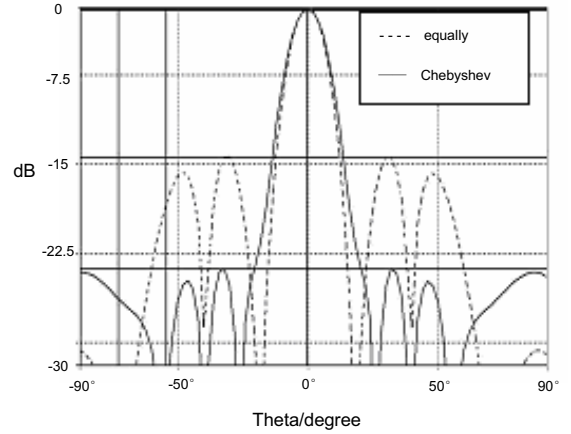


Fig.4 The comparison of theoretical calculation of side lobe level when $\phi=90^\circ$ between the equal structure and the Chebyshev structure

III. SIMULATION

The single-layer waveguide slot array antenna has been simulated respectively using HFSS and CST. The respective results of the radiation patterns of the antenna are shown in the Fig.5 and Fig.6. An agreement between simulation results of the two soft is demonstrated. The HPBW is 5.5° and the side lobe level is -29.6dB when $\phi = 0^\circ$, and the HPBW is 9.8° and the side lobe level is -20.1dB when $\phi = 90^\circ$. The gain of the single-layer waveguide slot array antenna is 28.5dBi .

IV. MANUFACTURE AND TEST

The cost of the antenna directly added the slot array using the soft material Rogers RT/duroid 5880 to the waveguide array is much lower than the metal structure using the Laser welding processing.

The single-layer waveguide slot array antenna is shown in Fig.8. The testing results of the radiation patterns of the antenna are shown in the Fig.5, Fig.6 and Fig.7. The HPBW is 5.7° and the side lobe level is -27.2dB when $\phi = 0^\circ$, and the HPBW is 10.7° and the side lobe level is -20.4dB when $\phi = 90^\circ$. The gain is 27.9dBi , and the bandwidth for $\text{VSWR} \leq 1.5$ is more than 500 MHz.

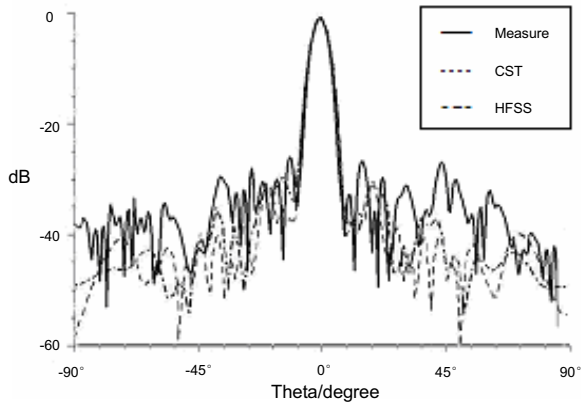


Fig.5 Radiation pattern ($\Phi = 0^\circ$)

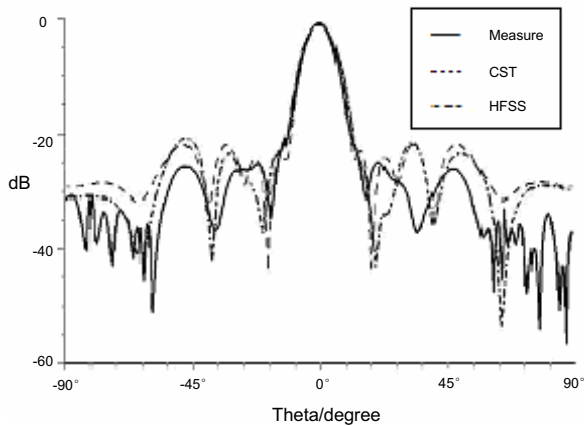


Fig.6 Radiation pattern ($\Phi = 90^\circ$)

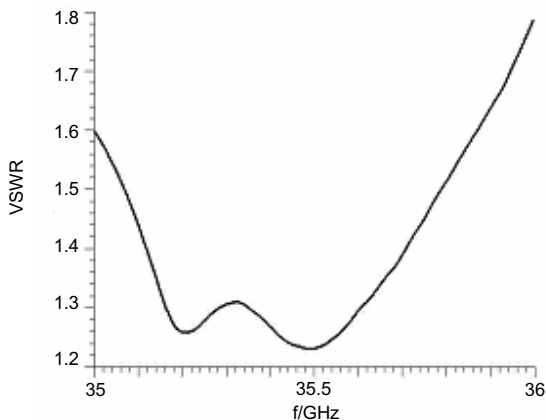


Fig.7 Measure result of VSWR

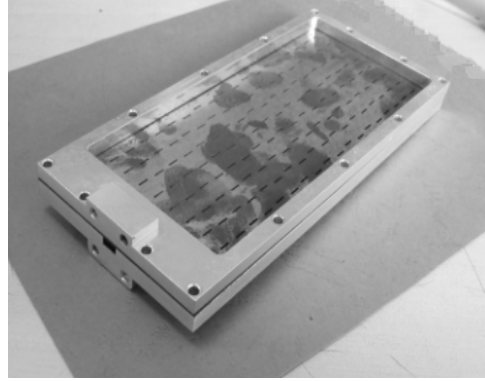


Fig.8 Single-layer waveguide array antenna

V. CONCLUSION

In this paper, we proposed a single-layer waveguide slot array antenna which waveguide array network designed by the Chebyshev power distribution realized high efficiency and good side lobe suppression. And the cost of manufacture is significantly reduced by binding the machine and the PCB processing technology feature. The measured and the simulated results agree with each other very well. The design, simulation, manufacture and testing methods of the proposed single-layer waveguide slot array antenna are verified.

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