# Chapter 6

# CONCLUSIONS

Five types of rectangular-cavity-backed slot antenna have been proposed in this dissertation. The realization of the circular polarization for the rectangular-cavity-backed slot antennas has been investigated. The optimization has been performed on both axial ratio and VSWR. The dual-band and wide-band operation has also been studied. The formulation for the analysis of the rectangular-cavity-backed slot antennas has been derived. A computer program based on the formulation has been developed.

In Chapter 2, the formulation for the rectangular-cavity-backed slot antenna has been derived. The moment method formulation of the analytical model, which is based on the application of the equivalence principle and the use of a generalized network formulation, is performed in this chapter. By applying the generalized network formulation to the slot aperture, the problem is separated into two regions, namely, the closed cavity and the outer space. By using the equivalence principle, the slot aperture is replaced by an equivalent magnetic current. The effect of the cavity on the magnetic current distribution is taken into account by introducing the Green's function inside the cavity. The only coupling is through the aperture, whose characteristics can be expressed by aperture admittance matrices, one for each region. These admittance matrices depend only on the region being considered, being independent of the other region. The aperture coupling is then expressed as the sum of the two independent aperture admittance matrices. This result can be interpreted in terms of generalized networks as two n-port networks connected in parallel with current sources. A computer program based on the formulation, which can be easily applied to the rectangular-cavity-backed slot-type antennas, has been developed.

In Chapter 3, three types of rectangular-cavity-backed slot antenna (a single square loop slot antenna, a two-element square loop slot antenna and a two-arm square spiral slot antenna) have been proposed to radiate circularly polarized waves. Characteristics such as input impedance, axial ratio and radiation pattern have been investigated. The effect of the structural dimensions on the antenna characteristics has been discussed.

Based on the numerical and experimental study, three important observations can be made. First is that by short-circuiting the slot on appropriate positions, an expected travelling wave current appears partly on the slot, and good circular polarization and symmetric radiation patterns are achieved. It should be pointed out that the axial ratio and magnetic current distribution are very sensitive to the positions of the short-circuiting points. Second is that the effect of the backing cavity dimensions, namely, the depth and width, on the antenna characteristics is significant. Especially the axial ratio and the center frequency are very sensitive to the size of the backing cavity. However, the effect of the cavity size on the radiation pattern and even the input impedance is not so serious. The last one is that compared to the single or two-element square loop slot antenna, the two-arm square spiral slot antenna has a wider axial ratio bandwidth and a more symmetric radiation pattern.

In Chapter 4, a rectangular-cavity-backed two-element rectangular loop slot antenna has been presented to radiate optimized circularly polarized waves. The optimization of the rectangular-cavity-backed two-element rectangular loop slot antenna has been performed on both axial ratio and VSWR. The characteristics of the two-element rectangular loop slot antenna have been examined numerically and experimentally.

The circular polarization is realized by introducing two short-circuiting points across the slots. The axial ratio is very sensitive to the short-circuiting positions. When the short-circuiting points are put at $1.08\lambda_0$ from the feed point, the lowest AR of 0.05dB is obtained. The antenna parameters are optimized so that the minimum AR and the minimum VSWR are at the same frequency, and the minimum VSWR is adjusted to 1.01, to ensure the minimum reflection. The effect of the ratio of the two side lengths of the slot is significant on both the bandwidths of AR and VSWR. When the ratio is 0.528, the bandwidths of AR ($\leq$3dB) and VSWR ($\leq$2) become the same and reach 7.6%. The VSWR minimum is almost unchanged with respect to the width of the cavity and the depth of the cavity, whereas the center frequency is dependent on both the width and the depth of the cavity. By adjusting the distance between the two rectangular loop slots, the input impedance value at the resonance can be readily controlled without affecting AR and VSWR characteristics. The AR and VSWR are insensitive to the distance between the two rectangular loop slots. Because of the symmetrical magnetic current distribution, the radiation patterns are symmetric in all of the $\phi$ planes.

The validity of the discussion has been proved by the experiment. The calculated and experimental results on the input impedance, VSWR, AR and radiation pattern are in good agreement.

In Chapter 5, a rectangular-cavity-backed single arm square spiral slot antenna has been presented to operate in a dual frequency band. The dual-band operation is realized by feeding the single arm square spiral slot at its outer turn. The characteristics of the rectangular-cavity-backed single arm square spiral slot antenna have been examined numerically and experimentally.

The parameters of the antenna are optimized that the VSWR bandwidths of the two operating bands are similar and are 5.0% and 5.8%, respectively. The VSWR's at the low resonance frequency and high resonance frequency are adjusted to 1.05 and 1.07, respectively, to ensure the minimum reflection.

The feeding position is important for sustaining the dual-frequency operation. The separation between the two resonance frequencies of the dual-band can be adjusted by changing the depth of the cavity. It has been found that the VSWR bandwidth can be enhanced by adjusting the distance between the single arm square spiral slot and the side wall of the cavity. By decreasing the width of the cavity, the wide band operation with the VSWR bandwidth of 11.4% is obtained. The calculated and experimental results on the input impedance and VSWR are in good agreement.

The computer codes developed here are flexible in which they can be applied to other rectangular-cavity-backed slot-type antennas. The numerical discussions give informative data to the engineering design of the antenna. As low-profile antennas with good circular polarization or dual band operation, this kind of rectangular-cavity-backed slot antennas has potential applications in some mobile communications, especially for spacecraft, satellites, airplane and automobiles.

The theoretical model used for the analysis is established on two assumptions that the width of the slot is very small compared with the wavelength and the conducting ground plane is infinitely large. The rectangular-cavity-backed wide slot antenna is the next topic worth of studying. For the wide slot there will be a magnetic current distribution across the slot, and the magnetic current distribution at the corner of the bent slot will be more complex than that of the thin slot. This kind of antennas is expected to be a wide band antenna. A rectangular-cavity-backed slot antenna with a finite conducting ground plane is also an interesting topic in the practical application. For the finite conducting ground plane, the current flowing on the surface of the conducting ground plane is changed and the diffraction at the boundary of the finite conducting ground plane should be considered. In addition, the use of dielectric or ferrite loading in the cavity is also an interesting topic that should be studied. The dielectric or ferrite loading in the cavity is expected to permit the reduction of cavity volume and aperture size at the expense of bandwidth and efficiency.

The above three topics on rectangular-cavity-backed slot antennas will be the next subject to be studied.