# Elliptical Slot-Ring Antenna for Multi-Frequency Operation

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## 1. Introduction

According to the advance of recent wireless communications such as ITS, GPS, Wireless LAN, Software Radio and so on, many frequency bands have been assigned and the compact antenna with multi-frequency operation has been watched with keenest interest, especially in the case of personal communications. Therefore the development of the compact antenna with low profile / light weight / multi-frequency operation has been one of the key technologies in these areas. For low profile and light weight antennas, the patch antenna and the slot antenna are recommendable among its candidates. As the bandwidth of these antennas is considerably narrow, for the multi-frequency operation, it is necessary to widen its bandwidth. In the case of the patch antenna, one way to widen the frequency bandwidth is to implement multiple layers in the design [1]. These multiple layers add to the weight, thickness, complexity and the cost of antenna. As the frequency bandwidth occupied for each service is generally narrow, if a single antenna can support multiple frequencies, the need for multiple-single frequency antenna is eliminated. And also the applications requiring different frequencies can be operated simultaneously with only one antenna element.

Regarding to the utilization of circular polarization, recently several reports has been presented [2], [3], [4], mainly being influenced by GNSS (Global Navigation Satellite System). As most of these works adopted the array configuration or multiple feeding points, there exists the disadvantage that the feed circuit becomes comparatively complex. Reference [5] has presented a multi-frequency operation slot-ring antenna with a single feed point, however, this antenna was linearly polarized.

Upon the above circumstances, in this paper, we propose an elliptical slot-ring antenna with a reflector board and present the simulation result as to the characteristics of this antenna by FDTD. This antenna is a single antenna with a single feed point for multi-frequency operation and generates a circular polarization at a specific operation frequency.

## 2. Antenna Configuration and Simulation Procedure

Figure 1 shows the schematic view of an elliptical slot-ring antenna proposed here. This antenna is fed by a 50Ω microstrip line under the substrate with the dielectric constant: $\varepsilon_r$ of 2.45 and the thickness: $h$ of 0.762mm. The major axis of an inner elliptical patch is inclined by 45 degrees with respect to the Y-axis and the center of this patch coincides with that of a neighboring outer circle with its radius of *OR*. Then, we can obtain an elliptical (strictly speaking, "quasi-elliptical") slot-ring antenna (ESRA). In this antenna, an elliptical patch is adopted in place of a circular patch [1] because in the multi-frequency operation, the use of an elliptical patch is expected to generate the circular polarization more easily and simply compared to the circular patch. In addition, this antenna has a reflector board that suppresses the backyard radiation and increases its antenna gain.

In this paper, we tried to design ESPA under the following objects, that is,

- This antenna is operated at triple frequencies,
- The circular polarization is requested at the lowest frequency with good return loss.

The polarization / return loss characteristics can be produced at a specific operating frequency by adjusting several structural parameters of this antenna. However, as this antenna has many parameters,

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we initially adjusted the length of a major axis: *IMJ* and a minor axis: *IMI* of the elliptical patch, but in this case, the reflector board is not existed. After determining the shape of an elliptical patch, by changing other structural parameters such as the radius of circle: *OR*, the stub length: *AC* and the offset length of microstrip line: *BC*, we could design ESRA with good polarization / return loss characteristics at triple operating frequencies. Next, ESRA with a reflector board was simulated in a same procedure, each parameter were slightly modified. Here, the length: *s* between the substrate and the reflector board was fixed at 0.762mm, that is, s is equal to *h*. The simulation was carried out by FDTD.

### 3. Simulation Results

First of all, as for ESRA without a reflector board, we adjusted the shape of an elliptical patch to produce the circular polarization. In this case, *OR*, *AC* and *BC* were fixed at 14.8mm, 2mm and 0mm, respectively. As a result, when *IMJ*=14mm and *IMI*=11.9mm, we could recognize a small second peak at the input impedance characteristics near the first resonant frequency band. This fact showed that this antenna could produce the circular polarization by fine adjusting, however, by only changing the shape of the elliptical patch alone, the input impedance characteristics was not controlled so well that good axial ratio could not be obtained. Secondly, by *IMJ* and *IMI* were fixed at 14mm and 11.9mm, respectively, we tried to control the input impedance by changing the structural parameters except for *IMJ* and *IMI*. Figure 2(a) presents the effect of the outer radius of circle: *OR* upon the input impedance when *AC*=2mm and *BC*=0mm are fixed. From this figure, we can see that enlarging *OR*, the real part of the second peak increases, while the imaginary part of the second peak decreases. Figure 2(b) presents the input impedance with respect to the stub length: *AC* when *OR* was fixed at 15.3mm according to the result of Fig. 2(a). As can be seen from this figure, as *AC* becomes larger, the change of the first peak increases and the effect upon the second peak decreases, and also the shift of the resonant frequency is small. Figure 2(c) shows the input impedance with respect to the offset length of microstrip line: *BC* when *OR* and *AC* are fixed at 15.3mm and 2mm, respectively, referring to the above results. This figure shows that as *BC* enlarges, the input impedance of the first peak becomes smaller while that of the second peak becomes larger and especially, the change of the imaginary part of the input impedance is remarkable.

Considering the tendency of the input impedance characteristics due to the structural parameters synthetically, we determined the values of the structural parameters in order to obtain the good axial ratio and return loss. Figure 3 shows the return loss characteristics of ESRA without a reflector board when *OR*, *AC* and *BC* were 15.3mm, 2mm and 6.6mm, respectively. Can be seen from this figure, the return loss characteristics at triple frequency bands are less than -10dB.

And also, Fig. 4 shows the axial ratio of ESRA without a reflector board. The axial ratio of around 0.5dB can be obtained at first operating frequency of 2.91GHz. As for polarization / return loss characteristics, it is recognized that ESRA without a reflector board has reasonable characteristics.

Figure 5 shows the example of radiation patterns of this antenna. As seen from this figures, in the cases of the first operating frequency (2.9GHz) and the second operating frequency (4.9GHz), this antenna has comparatively reasonable radiation patterns. And also seen that the former seems to be circularly polarized and the latter seems to be linearly polarized.

Next, we discussed ESRA with a reflector board. This reflector board is expected to suppress the backyard radiation and increase its antenna gain. According to the similar procedure to ESRA without a reflector board, the structural parameters are necessary to be slightly modified because of the change of the input impedance. As a result, the values of *IMJ*, *IMI*, *OR*, *AC* and *BC* became 14mm, 12.9mm, 14.8mm, 5mm and 4.4mm, respectively. These values are slightly different from those of ESRA without a reflector board. Figure 6 and 7 show the characteristics of the return loss and the axial ratio of ESRA with a reflector board. From these figures, we can see that although the operating frequencies become higher, both characteristics are almost reasonable except for ones at the third operating frequency (8.15GHz). As for the antenna gain, 7.98dBi at first operating frequency (4.45GHz) and 5.36dBi at second operating frequency (5.77GHz) are obtained at the zenith direction.

## 4. Conclusion

In this paper, we proposed an elliptical slot-ring antenna with a single feed point and a reflector board, and presented the characteristics of this antenna by the FDTD simulation. By the simulation, for example, we can see that the value of return loss is less than –10dB at triple operation frequencies and the axial ratio is around 0.5dB at the lowest operation frequency. And also seen that the radiation pattern and antenna gain are almost reasonable except for that at highest operating frequency. By adjusting the structural parameters of this antenna minutely, it is expected that good return loss, radiation pattern and antenna gain can be obtained at multiple operating frequencies. And also the required polarization can be determined at a specific operating frequency. Therefore, this antenna may be utilized in many wireless systems.


**Reference**

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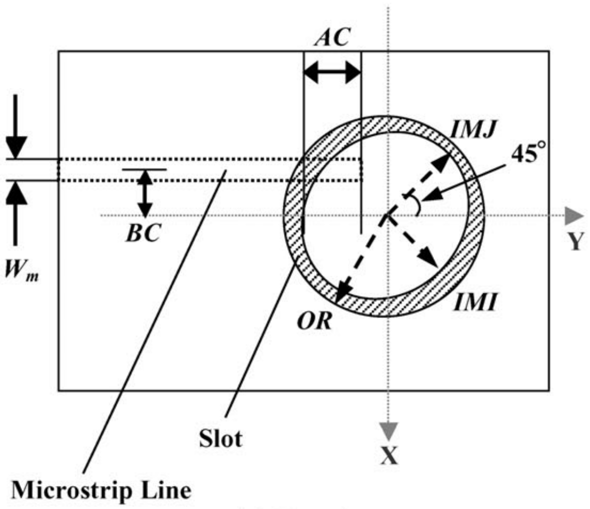
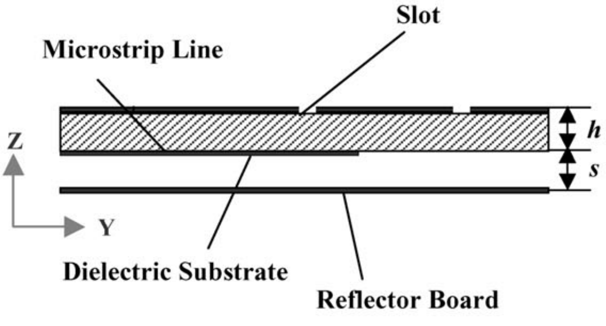
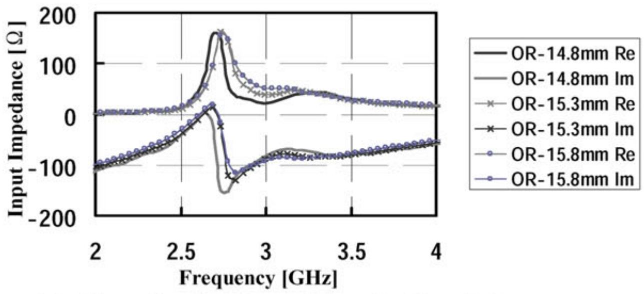



(a) Top view

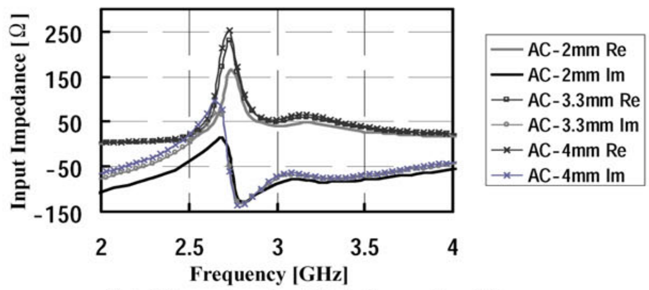



(b) Side view

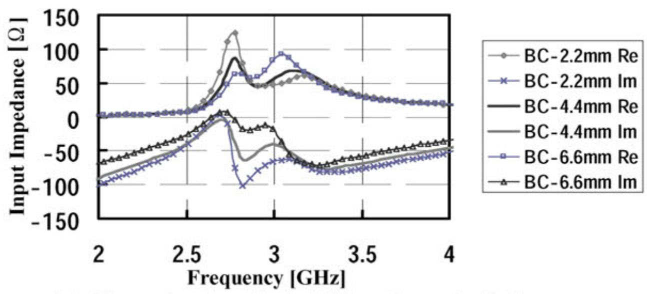
Figure 1 Configuration of ESRA




(a) Changing by Outer Ring Radius:*OR*




(b) Changing by Stub Length:*AC*




(c) Changing by Stub Offset Length:*BC*

Figure 2 Input Impedance characteristics of ESRA without a Reflector Board

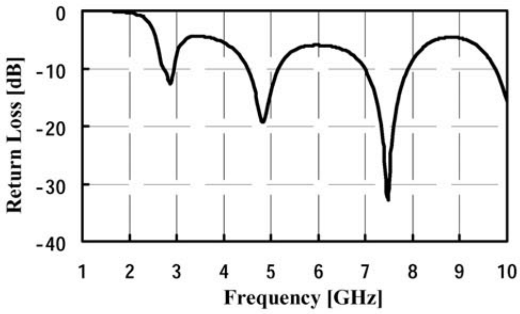


Figure 3 Return Loss of ESRA without a Reflector Board

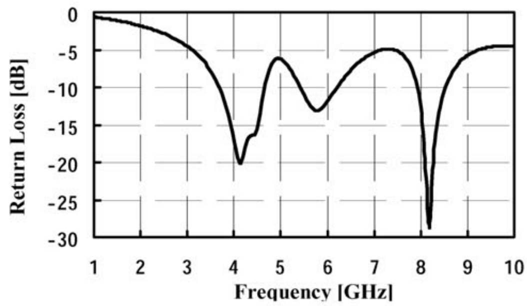


Figure 6 Return Loss of ESRA with a Reflector Board

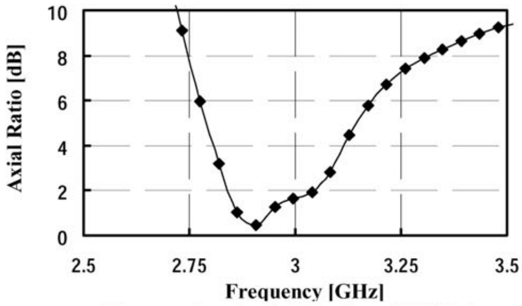


Figure 4 Axial Ratio of ESRA without a Reflector Board

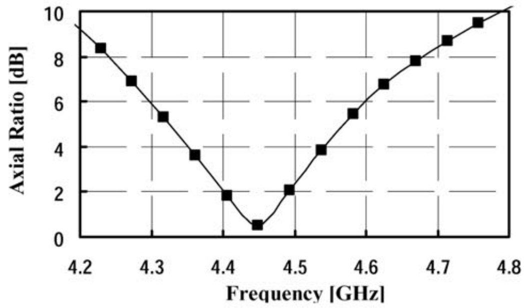
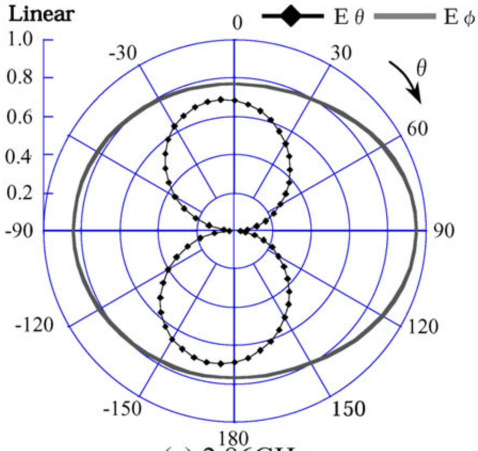
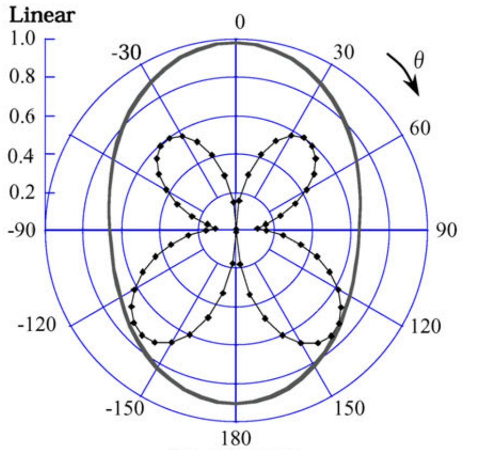


Figure 7 Axial Ratio of ESRA with a Reflector Board

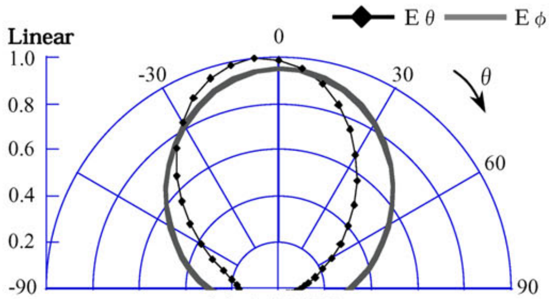


(a) 2.86GHz

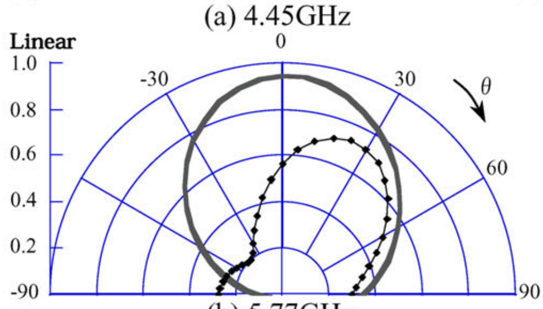


(b) 5.50GHz

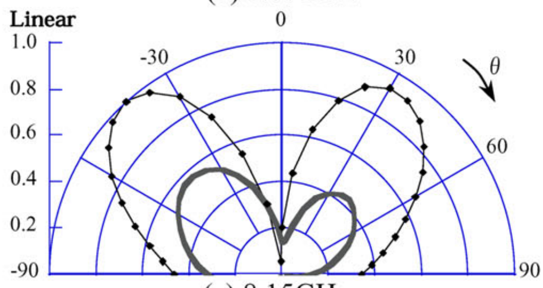
Figure 5 Radiation Pattern of ESRA with a Reflector Board (XZ-Plane)



(a) 4.45GHz



(b) 5.77GHz



(c) 8.15GHz

Figure 8 Radiation Pattern of ESRA with a Reflector Board (XZ-Plane)