Slot coupling control for a novel edge slot array fed by a rectangular single-ridged waveguide

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1. Introduction

An edge slot array on a narrow wall of a rectangular waveguide is widely used for various radar systems [1]. Tilted transversal slots are arrayed at a spacing of a half guided wavelength and slot coupling of each slot is controlled by the tilted angle. This array radiates horizontal polarization. On the other hands, a typical slot array using a single-ridged waveguide is arranged on an opposite broad wall to the ridge [2]. Slot coupling of a longitudinal slot on the broad wall is controlled by the slot offset. The ridged waveguide is often used for shorting the slot spacing as well as miniaturization of the waveguide. This array radiates vertical polarization.

A novel edge slot array using a rectangular single-ridged waveguide is proposed [3]. A thin single ridge is situated at a center of the narrow and the slots are arrayed on the same narrow wall straddling the ridge. In order to avoid producing grating lobes and to excite the slots in-phase, the staggered slots are arranged at an interval of a half guided wavelength. However, slot coupling control by the slot offset is not available since the current distribution on the narrow wall is constant to the transversal direction. In order to solve this problem, another slot is adjoined transversely to the original slot on the narrow wall straddling the ridge [3]. Because two slots are excited out-of-phase, the total radiation from the combined slot is controlled by a combination of lengths of the two slots. Furthermore, the combined slot can be a resonant slot by setting two slots to inductive and capacitive, respectively. This edge slot array radiates vertical polarization.

This paper presents slot coupling control of two separated slots for a edge slot array fed by a single-ridged waveguide. Figure 1 presents a configuration of the edge slot array consisting of the two separated slots. The slot pair is arrayed on the ridged narrow wall at a spacing of approximately a half guided wavelength. Radiation power as well as a resonant condition of the slot pair are obtained by using Ansoft HFSS for design of the array. It is exhibited that the slot pair can realize a wide control range of the radiation power and good return loss characteristics.

2. Analysis model of a unit slot pair

Figure 2 presents an analysis model of a unit slot pair of the edge slot array. Two separated slots with a different length straddle a ridge on the narrow wall of the rectangular waveguide. The design frequency is set to 6.0 GHz. Dimensions of the ridged waveguide are chosen to $a = 10.2$, $b = 22.9$, $t = 1.2$, $t_r = 0.1$, and $h_r = 14.0$, all in mm, as shown in Fig.2, to realize single mode propagation at the design frequency. A cut-off frequency of the ridged waveguide is 5.25 GHz. Uniform transversal currents with opposite directions flow on the narrow wall straddling the ridge. In this case, it is impossible for longitudinal slots to control the slot coupling by the slot offset.

Slot coupling of the slot pair can be controlled by lengths of the two slots $l_1$, $l_2$ and a width of the slots $w_s$. In order to realize a resonance of the slot pair as well as to obtain different radiation power, $l_1$ and $l_2$ are set to larger and smaller than a half guided wavelength, respectively. Radiations from the two slots are cancelled out each other because they are excited out-of-phase.
an inductive component of the longer slot S1 is cancelled out by a capacitive component of the shorter slot S2 by tuning \( l_1 \) and \( l_2 \) appropriately to be resonant. Waveguide ports are set on the both ends of the waveguide and radiation boundary conditions are assumed in the external region of the slot pair. Scattering parameters and radiation patterns of the unit slot pair are obtained by using Ansoft HFSS.

### 3. Performance of the slot pair

Figures 3 (a) and (b) present radiation power and transmission phase of the slot pair as a functions of \( l_2 \) for weak coupling case (\( w_s = 0.1 \) mm), respectively, where \( l_1 \) is set to 27, 29, and 31 mm. For these cases, the radiation powers are maximized at \( l_2 = 21 \) to 24 mm and are rapidly decreasing as \( l_2 \) becomes larger, since radiation from the longer slot S1 is cancelled by that from the shorter slot S2. The maximum radiation power of 19\% is obtained for \( l_1 = 27 \) mm because it is close to a resonant length of a single slot of around 25.5 mm. As is shown in Fig. 3 (b), the transmission phase is decreasing from positive value to negative one as \( l_2 \) is increased, since inductive component of the longer slot S1 is cancelled by capacitive component of the shorter slot S2. Resonance of the slot pair is defined by zero transmission phase. The resonant slot pair is observed at \( l_2 = 20 \) to 22 mm for \( l_1 = 27, 29, \) and 31 mm. Radiation power of the resonant slot pair depends on the combination of \( l_1 \) and \( l_2 \), as shown in Fig. 3 (a).

Similarly, Figs. 4 (a) and (b) present radiation power and transmission phase of the slot pair for strong coupling case (\( w_s = 0.5 \) mm), respectively. Larger radiation power of 22\% to 44 \% is obtained by the resonant slot pair with a larger slot width of \( w_s = 0.5 \) mm. Thus, radiation power of the resonant slot pair also depends on the slot width \( w_s \) as well as lengths of the two slots \( l_1, l_2 \). To summarize the discussion above, Fig. 5 presents a relationship among lengths of the two slots \( l_1, l_2 \), the width \( w_s \), and the radiation power in case that the slot pair becomes resonant. The radiation power is controlled up to 45\% by the resonant slot pair, which is enough performance for design of the array.

Figure 6 presents return loss characteristics of the slot pair, where \( l_1 = 29 \) mm, \( l_2 = 20.95 \), and \( w_s = 0.1 \) mm are a combination of the resonant slot pair for weak slot coupling. The reflection is well suppressed below –26 dB and the radiation power is 9\% at the design frequency of 6 GHz. Figure 7 presents E- and H-plane radiation patterns of the slot pair with the same parameters at 6 GHz. Typical radiation patterns similar to those of a single slot are confirmed.

### 4. Conclusions

This paper discusses slot coupling control of two separated slots for an edge slot array on a narrow wall of a single-ridged waveguide. In order to obtain various radiation power and to realize a resonance of the slot pair, lengths of the two slot \( l_1, l_2 \) are set to larger and smaller than a half guided wavelength, respectively. A width of the two slots \( w_s \) is also one of the important parameters to control the radiation power. Radiation power of up to 45\% can be realized by the resonant slot pair and good return loss characteristics are confirmed by using Ansoft HFSS. The slot pair can be applied for the array design in the future.

### References


Figure 1: Configuration of a novel edge slot array fed by a single-ridged waveguide.

(a) Cross-sectional view                                        (b) Top view

Figure 2: An analysis model of a unit slot pair of the array.

Figure 3: Radiation power and transmission phase of the slot pair ($w_s = 0.1$ mm).

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<thead>
<tr>
<th>Slot Length ($l_2$) [mm]</th>
<th>Radiation Power [%]</th>
<th>Transmission Phase [deg.]</th>
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<tbody>
<tr>
<td>$l_1$ = 27 mm</td>
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<tr>
<td>$l_1$ = 29 mm</td>
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<td>$l_1$ = 31 mm</td>
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<td>Resonance</td>
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Figure 4: Radiation power and transmission phase of the slot pair ($w_s = 0.5$ mm).

Figure 5: Radiation power of the resonant slot pair.

Figure 6: Return loss characteristics of the slot pair.

Figure 7: Radiation patterns of the slot pair.