Wideband Design of Feed Structure for 2×2-Element Waveguide Slot Arrays by Filter Design Theory

Takashi Tomura* [1], and Jiro Hirokawa[1]

(1) Tokyo Institute of Technology, Tokyo, Japan 152-8552

Waveguide slot array antennas have realized high efficiency, high gain and wideband characteristics in millimeter wave band (T. Tomura, et al., IEEE Trans. Antennas Propag., vol. 62, no. 10, pp. 5061-5067, Oct. 2014). The antenna structures were designed by numerical optimization and the optimized results do not give clear physical meaning of the optimized antenna structure. To reveal physical meaning of antenna structure and give clear design methodology, filter design theory (R. J. Cameron et al., “Microwave Filters for Communication Systems: Fundamentals, Design, and Applications”, New York: Wiley, 2018) has applied to design of waveguide slot arrays. In this paper, wideband design methodology is clearly shown for feed structure of 2×2-element waveguide slot array antennas. It is expected that the bandwidth is doubled compared previous study (T. Tomura and J. Hirokawa, Int. Symp. Antennas Propag. (ISAP), WeP-12, Oct. 2018).

Analysis structure to extract external quality factor Q_{ext} is shown in Figure 1. It consists of an input waveguide, a coupling slot, a cavity and an output waveguide. The output waveguide has electrically small height not to disturb field distribution in the cavity. The external quality factor is calculated by frequency characteristics of transmission (J.S. Hong and M.J. Lancaster, “Microstrip Filter for RF/ Microwave Applications,” New York: Wiley, 2002).

In general, external quality factor Q_{ext} is expressed by $Q_{\text{ext}} = 1/(\omega_0 C_1 R_0)$, where ω_0, C_1, R_0 are resonant angular frequency, characteristic impedance of the waveguide and capacitance of the cavity, respectively. In the analysis model, characteristics impedance of rectangular waveguide $R_0 \propto b_i/a_i$ and capacitance of the cavity $C_1 \propto l_{c1}w_{c1}/t_{c1}$. Therefore, the external quality factor $Q_{\text{ext}} \propto (a_i / b_i) \cdot (t_{c1}/l_{c1}w_{c1})$.

The thickness of the cavity and waveguide is varied to control external quality factor Q_{ext} whereas the width of cavity is changed to control resonant frequency. External quality factor Q_{ext} is shown in Figure 2. As expected, the external quality factor increases by t_{c1} and decreases by b_i. When b_i = 1.2 mm, the external quality factor shows minimum point contrary to the equation. This is because the capacitance of the cavity is increased due to the change of the width of the cavity larger than that by its height. As a result of the parameter analysis, the external quality factor is decreased up to 9.8 (9% bandwidth) from 17.6 (5% bandwidth).

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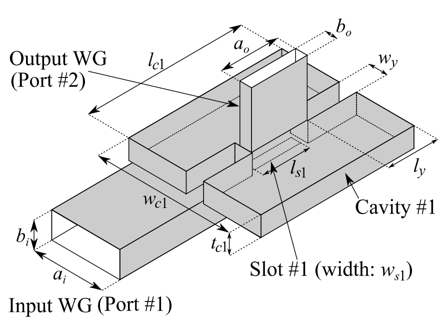

Figure 1. Analysis model.

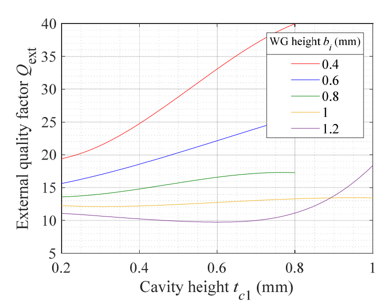

Figure 2. External quality factor Q_{ext}.