Chapter 3
Analytical and Calibration Models for Slot Antennas

Kok Yeow You
Universiti Teknologi Malaysia, Malaysia

ABSTRACT

In this chapter, the background, analytical formulations, and calibration routines for slot antennas are briefly reviewed. Performance and operating frequency of the slot antenna are strongly dependent on the dimension and shape of the slot or slotted array on the antenna. Nowadays, most antennas are designed using numerical simulation software for accuracy in analysis. However, analytical formulations still play an important role in the pre-design of the antenna due to the numerical simulation which still requires relatively long period of computation time compared to the analytical calculation. The predicted dimension of the antenna from analytical calculations will only require minor adjustment to optimize its performance in numerical simulation. Hence, the time spent for the antenna design can be shortened. Besides the performance of antenna, the antenna calibration process is crucial as well for releasing systematic errors in the antenna measurements. Some one-port calibration methods are described in detail.

INTRODUCTION

The antenna is an important element for today's technological developments, especially in industry 4.0 practice, Internet of Things (IoT) development, and 5G communication applications. In this chapter, only the types of slot antennas will be introduced and described; since the slot antenna has a simple structure, cost effective, and provide several advantages of usage in certain applications. This chapter focuses more on modeling and calibration of slot antenna. The background principle of slot antenna can be referred to a simple slot antenna, which consists of a narrow slot cut in a thin metal sheet and the slot is excited by a voltage source as shown in Figure 1 (a). The slot radiates waves in a way similar to a dipole antenna (in Figure 1 (b)).

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Babinet's principle states that the radiation field of the slot is the same as that for the dipole, but the field vectors over the slot are perpendicular to the corresponding field vectors in the case of the dipole (Booker, 1946). It has been shown that the voltage distribution (electric field) in the slot is identical to the current distribution on the dipole antenna. The impedance, Z relationship between slot antenna and dipole antenna can be written as:

$$Z_{slot} Z_{dipole} = \frac{\eta^2}{4} \tag{1}$$

where Z_{slot} and Z_{dipole} are the impedance of the slot antenna and dipole antenna, respectively. While, η ($\approx$ 376.99 Ω) is the intrinsic impedance of free space.

Once the complex value of Z_{dipole} is obtained, the Z_{slot} can be easily found as:

$$Z_{slot} \approx \frac{35530.57}{Z_{dipole}} \tag{2}$$

However, slots cut for the practise slot antenna is not always on the extended thin flat sheet of metal. In the slot antenna design, the slots cut can be either on the wall surface or cross section of the waveguide. Hence, the slot antenna can be categorized into several groups, such as annular slot antenna, waveguide slot antenna, cavity-backed slot antenna, waveguide-fed slot antenna, coaxial-fed slot antenna, and microstrip-fed slot antenna. For instance, the coaxial-fed slot antenna has been widely used as an antenna in underground long tunnels, mines, subway or underground parking spaces, due to the weak propagated radio signal in underground whereby the signal is screened by concrete walls or building. On the other hand, the waveguide-fed slot antenna is usually implemented in radar applications since it is simple, space saving and relatively low cost compared to parabolic reflector and horn antennas. Furthermore, microstrip-fed slot antenna is generally used in mobile phones, which appeared to be wideband, low profile, space and cost savings.

Figure 1. (a) Simple slot antenna. (b) Simple dipole antenna