CHAPTER 1

Motivation of this research

The highly shaped-beam antenna was first developed to give approximately uniform coverage of the earth from satellite antenna [1-3]. Recently, the similar requirement but different application; that is, the indoor high speed data transmission: wireless local area networks operating in the millimeter wave, again attracts considerable attentions [4-7]. Due to the critical specification in link budget, the transmitted power has to be efficiently distributed over the coverage; the spatial fluctuation of the field strength has to be as small as possible (within 6dB) within the defined coverage area, whereas outside the coverage the field strength has to fall off rapidly. A shaped reflector antenna for 60GHz wireless LAN access point was developed [5, 6]. A circular footprint having the deviation from the average field strength less than 2.5dB in the far field was reported [5]. They comment that the practical imperfections such as axial and lateral feed displacement and mispointing of the feed on top of effects due to blockage by the feed-horn may contribute to spatial field variations [5]. The prototype Plexiglas dielectric lens shaped antenna was developed in indoor wireless LAN application [7].

Although several type of dish antennas and lens antennas were developed and proposed to be applied in 60GHz hyper LAN applications, they have a common disadvantage that the high precision mechanism is needed in fabricating those antenna. To resolve this problem, in this thesis, we developed novel shaped-beam antenna using planar printed circuit technology.

In this research, the structure under consideration is a line (current) source sandwiched between a metal reflector and dielectric slab (planar radome) coated with metal-strip array. The electromagnetic field excited by the line source is shaped after transmitting through the planar radome. In fact, such a class of structures is very similar to a grating antenna; the line source used here attempts to excite the guided waves in the structure. In view of the presence of grating (hereafter, the metal grating refers to metal strips or dielectric rods array), the guided wave becomes leaky wave radiating into free space. Since the line source is placed in the center of the structure, it excites the waveguide modes propagating along the $\pm x$ direction, resulting in the occurrence of two leaky waves. Combining the two leaky wave peaks and the radiation directly from the line source (space wave), a desired illumination pattern was synthesized.

Notably, the present antenna can not have the radiation characteristics (circular footprint and circular polarization) reported in the literature; however, the contribution of this research is to verify the design of highly shaped-beam antenna using the properties of leaky-wave and space-wave radiating from the structure under consideration. Such a type of leaky-wave structures has been studied intensively for their radiation characteristics by many researchers, and their applications mostly focused on the directional antenna design. To mention a few, the full-wave analysis for the one-dimensional or two-dimensional metallic periodic structures excited by a line source was carried out [9, 10]. The mode excitation from sources in two-dimensional electromagnetic band-gap waveguide using the array scanning method was studied [11]. The directive radiation from the structure with a line source in a meta-material slab made from the conducting cylinders array was analyzed using both the full-wave method and the homogeneous slab model [12]. The radiation characteristics of a leaky-wave antenna constructed by a periodic array of metal patches on a grounded dielectric substrate were investigated [13]. Moreover, radiation at broadside for the similar structure in [13] was studied based on a simple transverse equivalent network model of the structure [14]. In addition to the metallic periodic structures used in the leaky-wave antenna design, the dielectric periodic structures taken as the antenna superstrate also were widely employed; for example, a parallel plate photonic band-gap and periodic medium waveguides was investigated [15]; a planar electromagnetic band-gap antenna design with periodical dielectric layers above a ground plane and excited by a printed patch antenna was verified to be able to enhance the gain and radiation bandwidth [16, 17]. A new resonator antenna consisting of a woodpile electromagnetic band-gap material and a metallic ground plane was developed to have highly directive radiation pattern [18].

In addition to the fabrication and measurement of the shaped-beam antenna, we have carried out the theoretical studies for investigating its radiation characteristics. The purpose is to lay a rigorous mathematical foundation for the analysis of this class of shaped-beam antennas. Stress is placed on network representations to establish physical pictures of the wave processes and yield insight; besides, a systematic microwave network approach is employed. This building-block approach first breaks the cross-sectional geometry into constituent parts, analyzes each part rigorously, and then combines them into an input-output relation through the continuous of tangential electric- and magnetic- fields at the junction discontinuities. As shown in figure 1, the configuration of the antenna contains an oversized metallic waveguide filled with a dielectric layer coated with metal grating, a metal reflector, and a line source acting as excitation. To treat each of junction discontinuities between an oversized waveguide and sub-waveguides, the method of mode matching is employed. Thus, the structure is analyzed as a rigorous boundary value problem, so that the field distributions on the outmost surface can be determined accurately. Then, far-field radiation patterns from the outmost surface are obtained by calculating the Kirchhoff-Hygens radiation integrals for each individual modes and summing their contributions [8].

The organization of this thesis is described as follows. In the next chapter, firstly we will introduce the structure configuration and parameters of the planar shaped-beam antenna using metallic grating. Then, the mathematical formulations, including the mode-matching method and equivalent principle, used for obtaining the far-field radiation pattern will be highlighted. The measured and numerical results obtained from our codes will be demonstrated in the end of this chapter. In chapter 3, we will introduce the structure configuration and parameters of the planar shaped-beam antenna using dielectric grating, and the numerical results obtained from our codes will be demonstrated. Finally, in the chapter 4, some remarks will be given to conclude this thesis.