学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

A Study on Gain Enhancement of Leaf-Shaped Bowtie Slot Antenna for Use in Quasi-Millimeter Wave Frequency Band
（準ミリ波帯に向けた葉状ボウタイスロットアンテナの高利得化に関する研究）

This thesis dissertation proposes to design a high gain antenna structure with a wide bandwidth. The antenna structure is designed to operate within quasi-millimeter wave frequency band.
The demand of high data rate transfer through wireless communication medium has been surging. Mobile users need a high-speed data transfer for daily usage such as high-resolution video stream and gaming. Due to the scarcity of spectrum within microwave frequency band, millimeter wave frequency band has been proposed and explored for potential application. 28GHz frequency band is more favorable and expected to significantly use in future 5G communication. High-gain antenna is required to compensate large propagation attenuation of millimeter wave frequency band. To increase coverage area and capacity of the overhanging station, large number of antennas are required to install. To efficient use the overhanging with such a distributed antenna system, the antenna frequency must be shared regardless of frequency band. Therefore, wideband antenna is required to use in such a distributed antenna system.
To have a high gain antenna structure, array configuration is promising technique. In this research, leaf-shaped bowtie slot antenna, which contains a wide impedance bandwidth characteristic of self-complementary antenna, has been adopted as radiating element of linear array configuration. In addition, leaf-shaped bowtie slot antenna has high gain and wide gain bandwidth characteristics. Moreover, leaf-shaped bowtie slot antenna and its feeding circuit have low profile which is suitable for large scale array structure. In this research, a linear array of 4 leaf-shaped bowtie slot antenna has been proposed for use within quasi-millimeter wave frequency band. In addition, two structures of feeding circuit have been used with the slot antennas array configuration. First structure is feeding circuit with microstrip line and conductor probe, which is used as connection between microstrip line and ground plane vicinity of radiating slot element. Second structure is the feeding circuit with quarter wavelength matching circuit.
Partially Reflecting Surface (PRS) has been used as gain enhancement technique, which is based on multiple reflecting, to increase gain of planar and aperture slot antenna. Based on PRS concept, dielectric superstrate with high relative permittivity has been applied as gain enhancement technique of aperture slot antenna. Therefore, in this research, gain enhancement technique based on dielectric superstate reflector has been applied to further increase gain in addition to array configuration technique. In this research, two layers of dielectric superstrate have been proposed to use as gain enhancement technique. This technique is considered as low cost, effective and efficient technique.
The results and discussions which is obtained from this research are summarized as following, and the significance of this research is clarified.
Chapter 1 describes the background and outline of this research.
Chapter 2 Computational electromagnetic is briefly discussed. In addition, the Finite Difference Time Domain method is the main topic for discussion. However, only a small part of Finite Difference Time Domain is discussed. This review is helping to comprehensively use the commercial simulation (software) Sim4Life in an effective and efficient way.
Chapter 3 describes the background of leaf-shaped bowtie slot antenna for use in ultra-wideband communication systems (UWB). In this research, instead of microstrip tapered line matching circuit, quarter-wavelength matching circuit has been proposed and designed as feeding circuit of leaf-shaped

bowtie slot antenna for use in UWB systems. As the results, impedance bandwidth of the antenna structure has been increased by around 9

Chapter 4 describes the background of leaf-shaped bowtie antenna for use in millimeter wave frequency band. Since feeding circuit of leaf-shaped bowtie antenna is unsuitable for large scale array, an array of 4 leaf-shaped bowtie slot antennas has been proposed for use in millimeter wave frequency band, in this research. Since leaf-shaped bowtie slot antenna has bi-directional radiation pattern, a flat reflector has been placed under dielectric substrate to make radiation pattern unidirectional. Two structures of feeding circuit have been used with linear array of 4 leaf-shaped bowtie slot antenna. First feeding circuit structure consists of microstrip line, conductor probe and microstrip tapered line. Conductor probe is used as connection between microstrip line and ground plane vicinity of radiating slot. Tapered line is used as impedance matching at input port. The leaf-shaped bowtie slot antennas array, which is fed by first feeding circuit structure, offers 490MHz of impedance bandwidth and 13.17dBi of maximum actual gain. Second feeding circuit structure consists of quarter wavelength matching circuit which is used as impedance matching. The leaf-shaped bowtie slot antennas array, which is electromagnetically fed by the second feeding circuit structure, offers 1.68GHz of impedance bandwidth and 13.7dBi of maximum actual gain. Therefore, the second feeding circuit structure consisting of quarter wavelength matching circuit offers a wider impedance bandwidth.

Chapter 5 describes the background of gain enhancement technique. In addition, this research proposes to use two layers of dielectric superstrate as gain enhancement technique for leaf-shaped bowtie slot antennas array structures which are designed in Chapter 4. After two superstrate layers have been arranged on top of slot antennas array, which is fed by the first feeding circuit structure, impedance bandwidth has been widened and actual gain has been increasing. The obtained impedance bandwidth is about 1.22GHz, and maximum actual gain is about 20.5dBi. However, after two superstrate layers have been arranged on top of the second antenna structure, impedance bandwidth has been narrowed and actual has been increased. The obtained impedance bandwidth is about 1.45GHz and maximum actual gain is about 19dBi. The impedance bandwidth of the second antenna structure is wider than that of the first antenna structure although there is destructive effect from two superstrate layers. However, the maximum actual gain of the second antenna structure is about 1.5dB smaller than that of the first structure.

Chapter 6 describes the validation of proposed antenna structures which have been designed in Chapter 3 and Chapter 5. The protype of single slot antenna electromagnetically fed by quarter wavelength matching circuit has been fabricated. The antenna characteristics have been measured and compared with simulated results. The prototype of the first slot antennas array structure with two superstrate layers has been fabricated and antenna characteristics have been measured and compared with simulated results. The simulated and measured results are in a good agreement although there is small discrepancy.

Chapter 7 is a conclusion and summarizes of the results of the entire thesis dissertation. The quarter wavelength matching circuit does improve the impedance bandwidth of leaf-shaped bowtie slot antenna. Two layers of superstrate is considered as an effective and efficient technique to design high gain and wide bandwidth antenna structure. In addition, the superstrate layers can be used as cover of the antenna structure.