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著者(和文)	角誠
Author(English)	Makoto Sumi
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Doctoral Dissertation

Multiband Antennas Comprising Multiple Branches for M2M Applications

Makoto Sumi

Supervisor: Professor Jun-ichi TAKADA

Department of International Development Engineering
Graduate School of Science and Engineering
Tokyo Institute of Technology

The Machine to Machine (M2M) applications market has proliferated rapidly. Both antennas of remotely controlling various equipment using small wireless telecommunications module and antennas of realizing high precision positioning using the Global Navigation Satellite System (GNSS) are highly required to realize these applications. These antennas require multiband characteristics and linear or circular polarization waves. This thesis presents two antenna design techniques for M2M applications. A technique combining an off-center-fed dipole and folded elements for linearly polarized antennas is proposed. In addition, a technique using rectangular loops with gaps for circularly polarized antennas is proposed. Furthermore, some techniques for multiband are discussed. Numerical and experimental results indicate the effectiveness of the proposed techniques compared to conventional techniques.

First, a broadband printed antenna comprising trapezoid elements for small wireless telecommunications modules is proposed. The 800 MHz and 900 MHz bands are focused because these frequency bands are easy to use even in urban areas but it is difficult to shorten the antenna size due to the long wavelength. This antenna is based on off-center-fed dipole antennas. The antenna is folded to shorten the antenna size and the trapezoidal element can expand the frequency bandwidth due to the increase of current paths. A compact antenna with a VSWR bandwidth (≤2) of 28.9%, a low profile, and omni-directional pattern features was achieved with the size of 0.160λ×0.226λ at the lowest frequency (VSWR bandwidth (≤2)). The size of the substrate is 60×85 mm^2. In addition, the antenna efficiency is higher than 85% at the resonance frequency bands.

Secondly, a quad-band printed antenna comprising trapezoidal elements and rectangle strip elements for small wireless telecommunication modules is proposed. This antenna is based on the previous antenna and is slightly adjusted the antenna structure to enhance the bandwidth in the 700 MHz to 900 MHz for the new 700 MHz band in Japan. In addition, two strip elements are added to support the 2 GHz band. The antenna achieves operation in quad-bands: 700 MHz, 800 MHz, 900 MHz, and 2 GHz. The antenna can achieve a compact size with a VSWR bandwidth (≤2) of 27.5% in bands including 700 MHz, 800 MHz, and 900 MHz, and a VSWR bandwidth (≤2) of 10.6% in the band including 2 GHz. The antenna has a low profile and omni-directional pattern features with the size of 0.16λ×0.23λ at the lowest frequency (VSWR≤2). In addition, the antenna can form a figure eight in the vertical plane in all operating bands. Furthermore, the antenna efficiency is higher than 82% at the resonance frequency bands. These radiation pattern features and high antenna efficiency characteristics are well suited to M2M applications.

Thirdly, broadband rectangular loops with gaps for GNSS are proposed to get broadband circular polarization and impedance matching at the same time. Each rectangular loop is connected to each end of a feeding point. Two gap positions on the loops are set symmetrically with respect to the center of the structure to get circular polarization and a symmetrical radiation pattern. An AR bandwidth (≤3 dB) of 18% and a VSWR bandwidth (≤2) of 22% are obtained. The position of the two gaps on the rectangles and the length of the feeding are sensitive to the AR and VSWR. This antenna structure is suitable for M2M applications which use circular polarization because it has a broad bandwidth, uniform radiation patterns in the direction of the satellite, and high antenna gains.

Fourthly, the demand for precise positioning using GNSS has recently increased. Therefore, dual-frequency capability including the L1 band (1575.42 MHz) and the L2 band (1227.60 MHz) is needed to improve accuracy and robustness. A dual-band antenna configuration comprising dual-rectangle loops with gaps fed for GNSS is proposed. New small inner loops inside large outer loops based on our previously proposed antenna are added. Furthermore, these inner loops are connected to the outer loops for dual-band operation. The VSWR bandwidth (≤2) including the low band is 16.0%, and the VSWR bandwidth (≤2) including the high band is 7.4%. The AR bandwidth (≤3 dB) including the low band is 5.0%, and the AR bandwidth (≤3 dB) including the high band is 5.3%. The antenna gains of RHCP of 8.7 dBi in the low band and 8.9 dBi in the high band were obtained, respectively. The broad AR elevation patterns and the accurate phase center were obtained. This structure is well suited to precise positioning.

In this thesis, the effective antenna design techniques for linear and circular polarization waves were presented for M2M applications. The effectiveness of adopting the off-center-fed dipole antenna and the rectangular loops with gaps was shown. The antenna designs suitable for small wireless telecommunications modules and GNSS are proposed. These techniques can realize high functionality in the M2M industry.