博士論文（要約）

A Study on 10 GHz Antenna Based on RF-MEMS Tunable Metamaterials

(RF-MEMS 可変メタマテリアルの 10GHz 帯アンテナ応用に関する研究)

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In order to realize smart antenna for IoT (Internet of Things), we propose an active metamaterials-based CRLH (Composite Right Left Handed) antenna using RF-MEMS cantilevers to tune metamaterials properties and control spatial radiation beams. Firstly we design a metamaterials tunable J-shape unit that consist of a pair of symmetry J-shaped patches with length smaller than $\lambda_g/5$, possessing effective electromagnetic homogeneity. Thanks to the microstrip-based implementation that has advantage in directional antenna radiation, and the J-shape unit that compatible to MEMS process, RF-MEMS array could be applied as RF switches to tune metamaterials properties, and consequently active scanning leaky wave antenna could be realized by cascading periodical J-shape units. By actuating RF-MEMS On/Off, antenna dispersion property could be tuned, leading to continuous scanning radiation patterns from backward (around -30°) through broadside (0°) to forward (around +30°) in the frequency band around 9 GHz.

The experiments go in three steps. Firstly, tunable metamaterials property and scanning spatial radiation patterns were verified by electrically closinging the gaps in the J-shape units without integrating RF-MEMS. Then secondly dummy MEMS cantilever antenna (static OFF/ON status without voltage actuation) was developed with matamaterials-based antenna to verify the cantilever's function as effective RF switches. Experimental results demonstrated that RF MEMS cantilevers could play the role of RF switches, and cantilever should be carefully designed so that its RF close/open equivalence could be increased. Thirdly, after optimizing MEMS cantilever's parameters, the final active metamaterials-based smart antenna using RF-MEMS switches will be obtained.

In addition, two interesting topics are proposed. One is to explore the feasibility of digital tuning of programmable metamaterials-based antenna by gradually tuning the dispersion diagram. As eight J-shape patches are integrated in the leaky-wave antenna, and nine different gap-statuses are designed. The dispersion diagram is found to vary the transition frequency from 9.4 GHz to 8.7 GHz with a step of 0.1 GHz, thereby frequency-dependent scanning radiation patterns are realized. Moreover, thanks to the gradually varying dispersion diagram, a status-dependent which also means programmable scanning radiation patterns are acquired in the band from 9 GHz to 9.3 GHz. Another topic is to explore the 2D scanning metamaterials-based antennas, in which phase constant β in two orthogonal directions are tuned, such that half-sphere spatial scanning radiation patterns are able to be realized.

Key Words: active metamaterials, digital control, programmable, RF-MEMS, reconfigurable antenna, microstrip structure, J-shape, Leaky-wave antenna, composite right-left hand (CRLH).