論文 / 著書情報
Article / Book Information

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Title(English)	Study of One-body 2-D Beam-switching Butler Matrix with Short-slot 2-plane Couplers
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	電気電子工学	専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（ 工学 ）
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

This research activity is concentrated on the development of 2-D beam-switching network and its components. The author devised the short-slot 2-plane coupler and the one-body 2-D beam-switching Butler matrix to catch low insertion loss and small volume together for communication, radar, and other application. The objectives of the research are to analyze and utilize the characteristic of propagating and evanescent modes for design, fabricate, and evaluate short-slot 2-plane coupler and one-body 2-D beam-switching Butler matrix.

Chapter 1 has discussed the fundamental background and the outline of 2-D beam-switching circuit.

Chapter 2 has presented the theory of the short-slot 2-plane coupler and the considerations of its design and fabrication. Four modes (TE_{10}, TE_{20}, TM_{11}, and TM_{21}) are chosen as the selected propagating modes which have two-dimensionally orthogonal polarities of electric field distribution each other in the coupled region of the short-slot 2-plane coupler. To acquire four orthogonal outputs, the four selected propagating modes have same the coupling coefficient and the different propagation constants. The coupled region and the port branches are designed to satisfy operation conditions. Single short-slot 2-plane coupler substitutes a 4×4-way short-slot combined coupler which consists of short-slot two E- and two H-plane couplers. Especially, the short-slot 2-plane hybrid coupler works as $2^2 \times 2^2$-way 2-D beam-switching Butler matrix. The volume of the coupled region of the short-slot 2-plane coupler is a half of 4×4-way short-slot combined coupler's. The operating frequency band of the short-slot 2-plane coupler is restricted by the frequency characteristic of the four selected propagating modes. In that reason, it has narrow operating frequency band in comparison with the short-slot E- and H-plane couplers. The short-slot 2-plane hybrid (cross) couplers were achieved 2.3% fractional bandwidth to satisfy within -6.1±0.5 dB (less than 0.8 dB) transmission coefficients, less than -18.4 dB (-13.7 dB) reflection coefficients, and within -81.5±2.4º and -180.1±0.5º output phases with around 70% of volumes of conventional things.

Chapter 3 has proposed the wideband short-slot 2-plane coupler and the considerations of its design and fabrication. Among the propagating modes excluded the selected propagating modes, TE_{11}, TE_{21}, and TE_{30} modes (called the complementary modes) which have same (TE_{11}/TM_{11}, TE_{21}/TM_{21}) and quasi (TE_{10}/TE_{30}) polarities of electric field distribution affect the output of the short-slot 2-plane coupler. The propagating modes which possess same or quasi polarities can be merged as the combined mode. The flatness of the coupling coefficients and the phases of the propagating and the combined modes affect the operating frequency band. Although the outputs of the previous mentioned short-slot 2-plane coupler converge to a balanced amplitude at center frequency, the deviation of its outputs is increased because of the inflection points of the coupling

coefficients of the propagating and the combined modes. Design parameters of the coupled region are selected to shift the inflection points of the coupling coefficients of the propagating and the combined modes toward low frequency. Its operating frequency band is increased more than twice than the previous mentioned short-slot 2-plane coupler's without unnecessary volume increment. The dielectric-filled short-slot 2-plane hybrid (cross) couplers were achieved 6.1% fractional bandwidth to satisfy within -6.3±0.5 dB (less than 1.0 dB) transmission coefficients, less than -15.8 dB (-14.8 dB) reflection coefficients, and within -96.6±5.9º and -177.9±1.8º output phases.

Chapter 4 has proposed the one-body 2-D beam-switching Butler matrix and the considerations of its design and fabrication. Orthogonally stacked hybrid, cross, and phase shifter units are commutative. It indicates that the arrangement of two neighbored orthogonally stacked units can be switched, physically. Two orthogonally stacked same type units are overlapped to single unit. Overlapped short-slot two E- and two H-plane coupler components are substituted a short-slot 2-plane coupler. Un-overlapped short-slot E- and H-plane coupler components are maintained their own things. Because the cross coupler unit of the one-body 2-D beam-switching Butler matrix consists of 0° phase shifter, short-slot E-, H-, and 2-plane cross coupler components, the phase compensator unit should be attached to remove these phase differences. The phase compensator unit can be merged to neighbored phase shifter unit, except last phase compensator unit. Thus additional volume increment caused by the phase compensator is restricted single unit. Compare one-body 2-D beam-switching Butler matrix with conventional thing, its length can be reduced a half of conventional thing, minimally. In view of the volume of the 2-D beam-switching Butler matrix, it is also exactly same its length relationship. The one-body $4^2 \times 4^2$-way 2-D beam-switching Butler matrices made of brass was achieved 2.4% fractional bandwidth to satisfy within -13.6±3.2 dB transmission coefficients, less than -13.7 dB reflection coefficients, less than 0.97 dB insertion loss, less than 24.8º deviation of phase difference to the ideal, and 29.6% coverage (-3.9 dB) in the hemisphere.

Chapter 5 has proposed the wideband and the large-scaled one-body 2-D beam-switching Butler matrices and the considerations of those design and fabrication. One-body 2-D beam-switching Butler matrix is inherited the frequency characteristics from the wideband short-slot 2-plane coupler's. When the input and output ports of the large-scaled one-body 2-D beam-switching Butler matrix are not arranged a square ($n_1 \neq n_2$), several overlapping unit options are given to reduce the imbalance of the outputs. The one-body $4^2 \times 4^2$-way and $8^2 \times 8^2$-way (simulated only) 2-D beam-switching Butler matrices made of PPS covered with aluminum alloy were achieved 5.1% (2.5%) fractional bandwidth to satisfy within -16.7±4.7 dB (-33.7±21.0 dB) transmission coefficients, less than -10.3 dB (-7.5 dB) reflection coefficients, less than 4.17 dB (2.22 dB) insertion loss, less than 25.4º (43.4º) deviation of phase difference to the ideal, and 47.9% (38.8%) coverage (-3.9 dB) in the hemisphere.

Finally, Chapter 6 summarizes this study and present future study.