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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Beam-switching matrix to realize multi-beams with spatial orthogonality has attracted a great deal of attention due to its vast potential application on satellite communication, as well as 5G/6G terrestrial or non-terrestrial communication. Among various transmission line technologies available for millimeter-wave frequencies, the waveguide stands out by showing its inherent superiority with low loss. This doctoral dissertation accomplishes the theoretical analysis of the two-plane coupler having arbitrary coupling ratio in the H-plane and E-plane directions, and its application to two-dimensional beam switching matrices for the purpose of functionality enhancement and miniaturization.

Chapter 1 gives a brief introduction concerning the background, application and development of beam forming networks, including beam-switching matrices and lens-based antennas. The motivation of this dissertation comes up, which focuses on the exploration of the two-plane coupler realizing arbitrary coupling ratios and two-dimensional beam-switching matrices with the beam number other than a power of two and with a different number of beams in two orthogonal directions.

Chapter 2 presents a theoretical analysis of the two-plane coupler having arbitrary coupling ratios in the H-plane and E-plane directions. Based on two-dimensional even-odd method analysis, it is revealed that the essence to control coupling ratio of the two-plane coupler is to adjust comparative transmission phases among four types of the quarter models assigning electrical and magnetic walls on the two-dimensional symmetrical planes properly . In addition to usual coupling mechanism with equivalence to cascading of the H-plane and E-plane couplers, other two coupling mechanisms are also be introduced. Subsequently with the above-mentioned theory part, based on a hybrid of finite element method and mode matching method, a prototype of the two-plane coupler having $1{:}\sqrt{2}$ in the H-plane direction and $\sqrt{2}{:}1$ in the E-plane direction working from 27.0GHz to 29.5GHz, with an 8.85% fractional bandwidth, is designed and fabricated to verify the theoretical analysis. For both the simulated and measured results across the considered bandwidth, the reflections are all suppressed under -15dB, the deviation of the output amplitude is in no excess of 2dB and the phase digressions are less than 20°. In addition, the designing sample of a H-plane coupler and an E-plane coupler is provided, cascading of which can be equivalent to the two-

plane coupler. Comparing to the cascade of the one-plane couplers, the two-plane coupler gives downsize rates as 58.4% and 50.1% with regard to length and volume, respectively.

Chapter 3 introduces an two-dimensional one-body 3×3-way hollow-waveguide Nolen matrix using a two-plane unequal division coupler working from 27.65GHz to 28.85GHz, corresponding to a 4.1% fractional bandwidth. The variation of the transmission of the proposed two-plane unequal division coupler is within ±0.5 dB in amplitude and ±10° in phase over the considered frequency band. For the designed two-dimensional 3×3-way Nolen matrix, a 2.5 dB output port power imbalance and a 0.86 dB insertion loss in maximum are observed in simulation across the analyzed bandwidth. Far field measurements are implemented to verify the radiation performance and to evaluate the realized gain with a reference to a standard horn antenna. The maximum realized gain of the two-dimensional 3×3-way Nolen matrix at 28.25GHz is reached at boresight with a value of 15.5 dBi in measurement and 15.7 dBi in simulation. The minimum realized gain in measurement is obtained for a two-dimensionally tilted beam with a value of 12.0 dBi, while in simulation of 12.9 dBi. It is the first time that a two-dimensional one-body hollow-waveguide Nolen matrix with the port number other than a power of two is reported, also including the first application of a two-plane coupler having unequal output division to beam-switching matrix network. The future bandwidth enhancement could be explored by adopting more advanced manufacturing technologies, such as 3-D printing.

Chapter 4 introduces a two-dimensional hollow-waveguide 6×4-way beam switching matrix working from 27.25GHz to 29.25GHz, with a 7.1% fractional bandwidth. This is the first time that a two-dimensional waveguide beam-switching matrix is proposed with different number of beams in two orthogonal directions. Taking advantage of the two-dimensional symmetry in the transverse directions, the design complexity is reduced. The two-dimensional 6×4-way matrix has a 2.2 dB insertion loss over the operation bandwidth. The radiation performance is verified by planar scanning near-field measurements. The maximum directivity is obtained with a value of 21.3 dBi in measurement and 21.1 dBi in simulation. The minimum directivity in measurement is 17.7 dBi, with a tilted angle of 34° with reference to boresight, corresponding to a scan loss of 3.4 dB, while that in simulation is 18.0 dBi, with an tilted angle of 35° with reference to the boresight, counterpart to 3.1 dB scan loss.

Chapter 5 gives the overall summary to complete the dissertation, with some perspective views on potential future works, such as to enhance for the bandwidth of the two-plane coupler by introducing asymmetry in the longitudinal direction, and to accomplish the theoretical framework of one-dimensional generalized 2N-way matrix with symmetrical configuration.