Abstract—In this paper some recent progresses of beam steering technology based on the implementation of phased array of antennas for near-field focused (NFF) radiation are reported and compared for RFID applications at 2.4GHz band. In particular, the beam steering is based on the creation of discrete multi-beam radiations. The phased array of antennas is excited by a set of beamforming network (BFN) predetermined for coverage areas. Several useful BFN implementation methodologies are presented to achieve the desired patterns. Both numerical and experimental results are presented to compare the radiation characteristics and validate the designs.

Keywords—Beamforming network, Beam steering, Multi-beam radiation, Radio frequency identification.

I. INTRODUCTION

Radio frequency identification (RFID) is becoming popular in the internet of thing (IoT) applications. In many application scenarios, the target of identification is in the near-zone of RFID system [1],[2]. To achieve a better identification and avoid interferences from nearby metal subjects, near-field focused (NFF) radiation [1] is desired for antenna design, where phased array of antennas is popularly employed.

The drawback of NFF antennas is the limitation of target area due to the small spot of electromagnetic (EM) illumination. To extend the coverage area while in the meantime limiting the EM interferences, NFF beam steering appears to be a good solution, which may also expand the system capacity.

In this paper, we present several beamforming network (BFN) designs to radiate multiple predetermined beams to define a coverage area including dynamic beam switching by implementing phase shifters and passive multi-beam BFNs. The radiation characteristics will be compared based on numerical simulation and experimental measurements. Theoretical foundations to realize these antennas will be shown in the conference presentations.

II. APPLICATION SCENARIO AND SUMMARY OF BFN DESIGN

A. Application Scenario

An application scenario is first defined to better illustrate the NFF antenna design concept. Fig. 1 shows a multi-track factory transportation system for fast product monitor. In this case, we assume that a RFID reader is installed on the top side of the system, as illustrated in Fig. 1, with the phased array of antennas facing to the transportation belts to scan the RFID tags. The target zone is a rectangular area in Fig. 1, where the radiation is focused to illuminate the target zone. The NFF beams radiated from the antenna are focused by the spots to illuminate the RFID tags within this coverage area.

Fig. 1: An application scenario of multi-track transportation system.

B. Summary of BFN Designs for NFF Radiation

The antenna design concept first plots several illumination spots inside the coverage area. BFNs are then designed to excite the phased array of antennas that may radiate beams to illuminate the target spots. Three approaches of BFN design are summarized in this paper, whose radiation characteristics are then compared in the NFF beam formation. 

1) Single Beam Forming by Integrating Phase Shifters and Power Dividers

The most straightforward approach [3] employs phase shifters to excite the antenna elements which are then combined by using a multi-level power combiner to produce a RF port for RFID system. In this case, the beam is formed by varying the excitation phases from the phase shifters, whose phases are determined by the conjugated propagation phase from the antenna elements to the focus points in the spot area. In practical applications, these phases are pre-calculated and stored in the phase shifter controllers.

2) Passive Multi-Beam BFN based on Butler Matrix

The BFN approach based on conventional RF circuits and phase shifters sophisticates the RFID reader system because the phase shifters as well as their control system are generally expensive. Multi-beam BFN [4] based on passive RF circuits
may simplify the system architecture as the beams can be switched from one to another without the need to perform sophisticated beamforming. In the implementation of Butler matrix, an additional compensation circuit is designed to assure radiation energy focused in the target area by using a quadratic phase excitation. In this case, the conjugated phases in the previous section is expanded into DFT terms plus quadratic phase compensation.

3) **Rotman Lens based NFF BFN**

The narrow band characteristics of RF BFN can be improved by using lens based BFN. A Rotman lens structure to excite a planar array for NFF multi-beams has been developed [5]. The design concept employs three focal points on the circular arc of Rotman lens, and also selects three corresponding NFF beam focused points along a larger circular arc in the target zone. The profile of Rotman lens is thus determined by solving the three phase equations to result in the conjugated phases for antenna excitations, which can be found in a closed form formulation.

### III. RADIATION CHARACTERISTICS

Examples are shown to demonstrate the feasibility. The first case of programmable BFN for beam steering considers a target area of 30×80 cm² located at 90cm from the array aperture. The array has 64 patch elements with a λ period printed on a FR4 substrate. Due to the use of phase shifters, 16 NFF beams are pre-created to beam switching. Fig. 2(a) shows the overlapping of radiation contoured patterns (-3dB contour) [3] on the cross-section plane in the target zone. A proper overlapping has been observed.

In the design of NFF Butler matrix BFN, the antenna array is identical to that in Fig. 2(a). An 8x8 Butler matrix is employed to create the multi-beam excitations. The overlapping of multi-beam contoured patterns [4] is shown in Fig. 2(b), where the patterns have a better shape of patterns.

On the other hand, the period of array is reduced to 0.5λ for the case of NFF Rotman lens BFN. The NFF focused distance is 120cm to produce focused spots at roughly 80-90cm. The overlapping of contoured patterns [5] in the target zone are shown in Fig. 2(c). In this case, the beamwidths along the scan dimension are similar for the seven beams. Again the beams are properly overlapped.

### IV. CONCLUSION

The experimental results have demonstrated the feasibility to design NFF multi-beam BFN for RFID applications. Experimental results have validate the results. More results will be shown during the conference presentation.

### ACKNOWLEDGMENT

This work is financially supported in part by the Ministry of Science and Technology, and National Chung-Shan Science and Technology, Taiwan.

### REFERENCES


