A Novel mm-Wave Antenna Array Design for Future Metallic Casing Mobile Phone Applications

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***Abstract*— The design of a 28GHz beam-steering antenna for future fifth generation (5G) mobile phone applications is presented in this paper. The proposed cavity-backed slot antenna element can be implemented using metallic casing of mobile phone, while maintaining good performance in terms of gain and efficiency. The prototype array consists of four slot elements and a 4×4 Butler Matrix feed network. The Butler Matrix for beam switching in the far-filed is also integrated within the mobile phone mainboard to provide the needed phased array operation. Two arrays are built on the left- and right-side of mobile phone, and each array can offer beam steering at broadside for −43°,−15°, +15° and +43°, while the gain is higher than 12dBi. In addition, the simulated results show that the return loss of this array antenna is less than -10dB in the frequency range of 27.5 to 29GHz.**

Keywords—5G; Phase Array Antenna; Beam Steering; Butler Matrix; Cavity-backed Slot; Metallic Casing; Mobile Phone

I. Introduction

The fifth generation (5G) wireless access is the next step in the evolution of mobile communications, projected to be in place by 2020. The aim to 5G is to provide connectivity for any kind of device and any kind of applications that may benefit from being connected, including mobile connectivity for people and various objects in user's environment. To be able to achieve such connectivity, high data rate, low latency, and very high device density must be accommodated. Compared with 4G systems, there are three key technology challenges for the 5G mobile phone antenna: mm-Wave band, Beamforming/Beam-Steering, MIMO/Massive MIMO. The 5G systems shift the frequency to mm-Wave band to obtain wider bandwidths. The FCC (Federal Communications Commission) released the spectrum band plan in the US including bands potentially available for licensed and unlicensed 5G use in 2016, as shown in Fig. 1. The use of this higher frequency will call for a change of paradigm in the way mobile phone antenna frontends are designed. Not only mm-Wave antennas will have to integrated in the device, but also switching, beamforming topologies and algorithms will have to be developed specifically to meet the stringent requirements of mobile phone. As reported in [1]-[3], 28GHz beam steering antennas are designed for the 5G mobile devices, which are implemented using low cost substrates and maintain good performance. However, these antennas may not be very suitable for operating in realistic mobile phone project, especially for more and more popular metallic frame and casing industrial design of consumer electronics products. In addition, this design is not only for 5G , but is also compatible with 4G LTE.

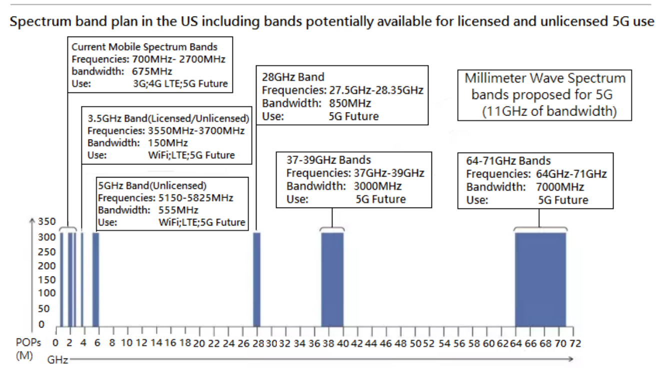

Fig. 1. FCC Spectum Band Plan in the US

In this work, we propose a novel 28GHz phased array antenna suitable for future 5G metallic casing mobile devices. The outline concept of the 28GHz antenna element and array are deduced from several key parameters in Section II. In addition, a 4×4 Butler Matrix feed network for this slot array antenna is also presented in Section II. Finally, the simulation results of the arrays are presented in Section III.

II. Array Antenna Configuration

Figure 2 illustrates the constituting components of the 28GHz beam steering antenna arrays. Two phase arrays built on left- and right-side of mobile phone, which back cover is made of metallic material, such as stainless steel, aluminum alloy and etc. The top- and bottom-side metallic frames of the mobile phone are used for 4G LTE main antenna, LTE diversity/ LTE MIMO antenna/NFC and GPS/WiFi antenna. Each array is composed of four cavity-backed slot elements and a 4×4 Butler Matrix feed network in the middle.

A. Antenna Element and Array Design

Each phase array consists of 4 elements, known as cavity-backed slot. Due to the 2-pages limit in here, the design of this cavity-backed slot and array configuration (for array 1 and array 2) will only be discussed in detail during the conference presentation. Because of the reflection of cavity, the radiation pattern of the element is directional.

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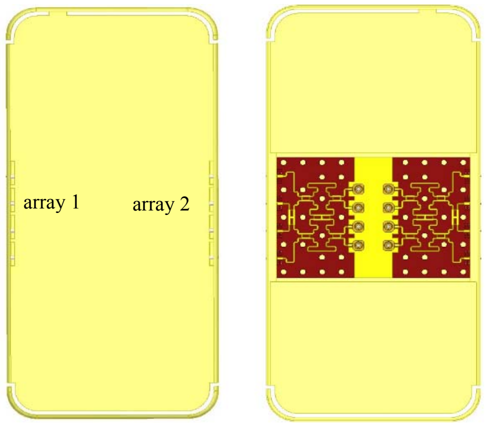

Fig. 2 Top and bottom view of the mobile phone

B. *Butler Matrix Network Design*

The array is fed by a 4×4 Butler Matrix network, which is most popular choice to provide the necessary bandwidth, scanning capabilities and beam width. In this work, each Butler Matrix consists of four hybrid couplers, two crossovers and two pairs of phase shifters to realize the required amplitude distribution and specified identical phase difference between output ports. The detail block diagram and simulation mode of proposed beam steering arrays are shown in Fig. 3 and Fig. 4, respectively. The four feeding ports of Butler Matrix are ports 1-8, and their corresponding outputs connecting to the antenna array are ports 9-16. The relationships between feeding ports and output phase differences are tabulated in Table 1. The Butler Matrix feeding networks are implemented using Rogers 5880 substrate (thickness= 0.254mm), which is integrated the SMP connectors .

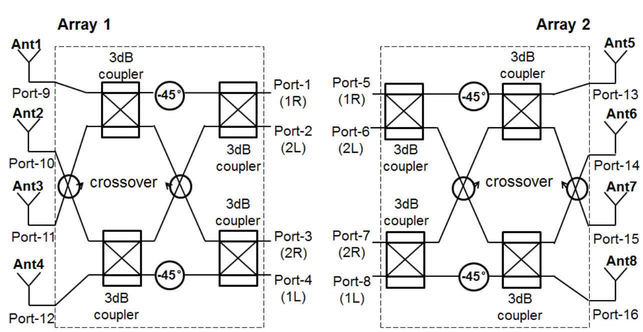

Fig. 3 Block diagram of 4×4 Butler Matrix networks

III. Results and Discussions

In this case, it is remarkable that the cavity-backed slot array arrangement has higher gain and well fits the restricted size specifications of mobile phone. These beam steering arrays were simulated using ANSYS HFSS V15. From the simulation results, the slot element at 28GHz can exhibit gain of up to 7dBi, and the array can obtain gain of more than 12dBi. At different feeding port excitation, uniform amplitudes with difference phase distributions can be achieve in the output ports which allow the designed array radiate beams tilted in angles of -43°,-15°,+15° and +43°.

Table 1 Relationship between feeding ports and output phase differences

Feeding Port	Port 1	Port 2	Port 3	Port 4
Output Phase Difference	135°	-45°	45°	-135°

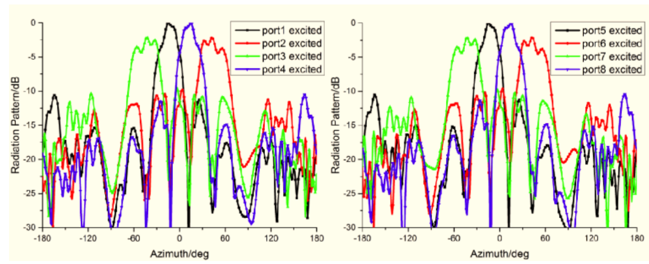

Fig. 4 Normalized radiation pattern of different feeding ports

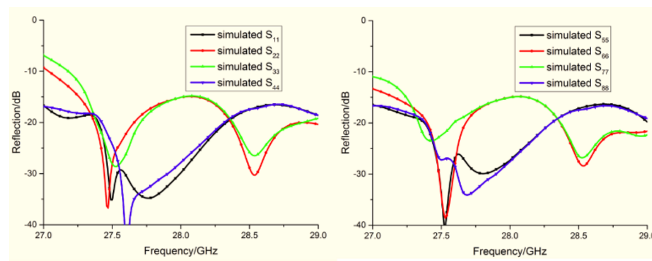

Fig. 5 The return loss of different feeding ports

The simulated normalized radiation patterns of proposed slot arrays are shown in Fig.4, and the return loss of the arrays are shown in Fig.5.

IV. Conculsions

A 28GHz beam steering antenna has been presented. It is noteworthy that the antenna array can be implemented in 5G metallic casing mobile phone applications. And the proposed antenna array has good performance in terms of S-parameter, gain, efficiency and beam steering characteristics.

References

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