MM-wave array antenna for 5G mobile handsets
－Dual-Mode Operation for Fully Metal-Covered 5G Cellular Handsets－

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Abstract A SAR reduced 28 GHz beam-steering array antenna with dual-mode operation using two subarrays for a fully metal-covered 5G cellular handset is proposed. The proposed antenna consists of two subarrays with 16 rotated slot antenna elements and the subarrays are selected according to its corresponding mode by using a switch. The proposed design is proven to have sufficient impedance-matching, a sufficient gain level, suitable beam steering characteristics, and a reduced SAR level. The calculated peak SAR values on head phantom for beam scan angles of 0° and 40° are 0.53W/kg and 0.88W/kg, respectively when the input power of each subarray is 24 dBm.

Keyword 5G, millimeter-wave, beam-steering array, fully metal-covered handset, SAR

1. Introduction

One of the promising technologies in 5G systems is the utilization of millimeter wave bands, along with beam-steerable phased array antennas, at both the base station and the mobile device. In particular, it is a difficult challenge to implement the phased array antenna within a mobile device because of its spatial limitation. Various studies on this issue have been carried out [1], [2]. However, relatively few studies have attempted to implement a 5G array antenna for metal-covered handsets, despite the fact that metal-body cellular handsets have recently been widely embraced. In related work [3], [4] beam-steering arrays with 8 elements on frames of a cellular handset with a metal casing were studied. However, these arrays result in extremely high SAR levels exceeding the current SAR limit on the user's head when the handset is in talk mode, because strong fields are radiated toward the user's head.

In this paper, to resolve the aforementioned SAR problem in talk mode while shaping beam pattern appropriate for data mode, we propose a 28 GHz beam-steering array antenna with dual-mode operation using two subarrays for a fully metal covered 5G cellular handset. (Fig. 1)

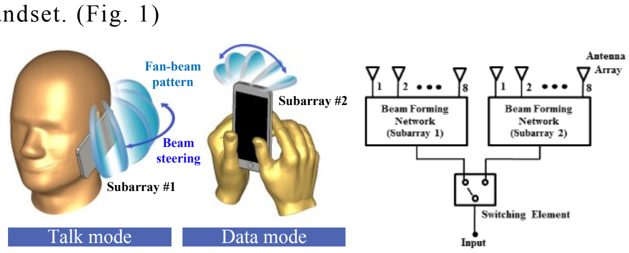
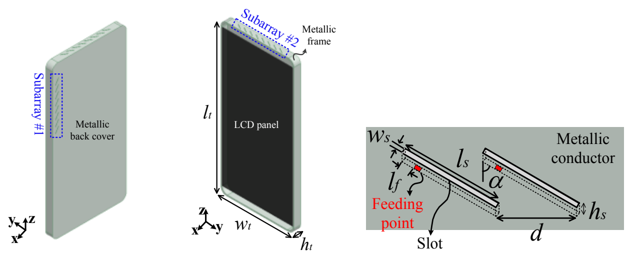


Fig. 1. The concept of beam-steering characteristics of the designed 5G mobile handset antenna for dual-mode scenario

2. Antenna Design

The proposed design consists of two subarrays each of which has 8 slot antenna elements. The subarray #1 is operated when the handset is in talk mode and placed on the back cover of the handset to reduce the SAR level toward the user's head, as shown in Fig. 2(a). On the other hand, when the handset is in data mode, it requires an array with a hemispherical beam coverage with respect to z-direction because the handset is held in hands or laid down on the flat surface. For this purpose, the subarray #2 is added and positioned on the upper frame of the handset. The overall dimension of the handset is 17.28 mm×67.1 mm×7.1 mm. The designed handset consists of an LCD shield, a metallic frame, and a metallic back cover. Fig. 2(b) shows an enlarged view of an arbitrary two elements of the proposed slot array. The slot length (l_s) and the distance between the elements (d) are approximately λ/2 at 28 GHz. The slot width (w_s) and the feeding location (l_f) are optimized for proper impedance matching.



(a) (b)

Fig. 2. (a) 3-dimensional configuration of the metal-covered handset with designed array antenna (b) detailed view of arbitrary two elements in the proposed slot array

3. Results and Analysis

The simulated S-parameters and the three-dimensional beam patterns, with gain values at different scan angles for each subarray, of the proposed structure are given in Fig. 3. The simulated -10 dB S11 bandwidth of subarray #1 and #2 are 1 GHz (27.2 – 28.2 GHz) and 1.3 GHz (27.2 – 28.5 GHz), respectively. The mutual couplings between elements of subarray #1 and #2 are less than –19.6 dB and –11.8 dB, respectively. The proposed antenna structure with subarrays #1 and #2 exhibits good beam steering characteristics in the *yz*-plane and *xz*-plane for the scan angles ranging from 0° to 60°. The beam steering characteristics are obtained by using the progressive linear phase difference among the excitation signals of the ports.

To assess SAR levels on the user's head by each subarray, the computed 1g-averaged peak SAR values on the skin-equivalent head phantom have been compared for each subarray with the beam scan angle of 0° and 40° (Fig. 4). The simulation set-up is shown in Fig. 1. The LCD shield faces the SAM head phantom. The input power of each subarray is set to be 24 dBm which is the maximum output power used for evaluating the SAR value of an LTE handset under power class 3 test. The calculated results

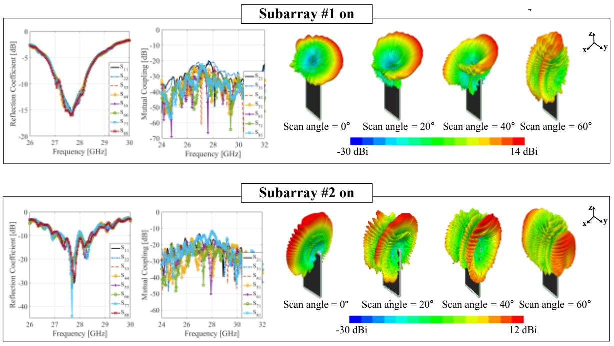


Fig. 3. The simulated S-parameters and the 3-dimensional beam patterns, with gain values at different scan angles, of the proposed array structure

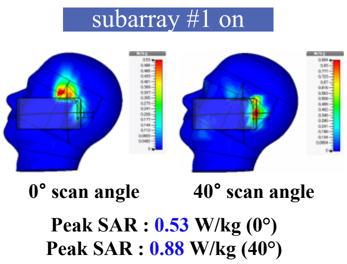
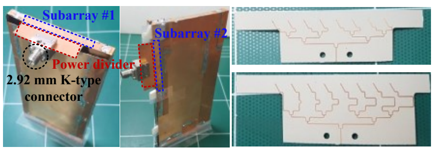


Fig. 4. Computed SAR distributions on the skin-equivalent SAM head phantom for the subarray #1 with the scan angle of 0° and 40° (28 GHz)



(a) (b)

Fig. 5. (a) the fabricated prototype of the proposed antenna with two subarrays (b) the beamforming networks with two fixed beam scan angles

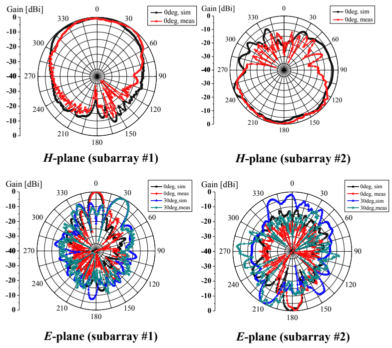


Fig. 6. The normalized 28 GHz *E*-plane and *H*-plane radiation patterns of two array antennas by the scan angles

show that The peak SAR values by the subarray #1, for scan angles of 0° and 40°, are 0.53W/kg and 0.88W/kg, respectively, which satisfy the IEEE, FCC, and ICNIRP SAR limits. On the other hand, the calculated peak SAR value for scan angle of 0° when the array is placed in the frame of the handset, as presented in [3], is 5.68 W/kg.

Fig. 5(a) shows a fabricated prototype of the proposed antenna. The microstrip coupled feeding technique using a substrate is utilized to implement the ideal lumped port used in the simulation. The beam forming networks, with two fixed beam scan angles (0°, 30°), are illustrated in Fig. 5(b), which are standard corporate designs with T-junction power dividers. To achieve a beam scan angle of 30°, fixed microstrip line delays in the network are employed. Fig. 6 shows the 28 GHz normalized E-plane and H-plane radiation patterns of the two subarrays. The simulation and measurement results show good agreement. The HPBWs of the measured H-plane patterns for two subarrays with 0° scan angle are 90° and 116°. The synthesized beams in the E-plane patterns are well formed for the scan angles of 0° and 30°.

4. Conclusion

A SAR reduced 28 GHz beam-steering array antenna with dual-mode operation for a fully metal-covered 5G cellular handsets is proposed. The proposed antenna is a good candidate for mm-wave 5G handset applications.

References

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