Impact of two-handed grip on quasi-omnidirectional coverage of mmWave 5G handset

Impact of Two-Handed Grip on Quasi-Omnidirectional Coverage of mmWave 5G Handset

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Abstract— In this study, we explore the impact of a two-handed grip on the coverage of a handset featuring three antenna arrays operating in the n257 frequency band of 26.5 GHz - 29.5 GHz. We focus on beam steering, which is effectively implemented using the antenna arrays and multi-bit phase shifters to provide quasi-omnidirectional coverage. We investigate how different hand grips impact the handset's coverage region, including clockwise (CW) and anti-clockwise (ACW) rotation of the handset. Our findings reveal that, for the CW two-handed grip, beam steering significantly increased the coverage region (in which gain is greater than 0 dBi) from 19.7% to 42.2% of the spherical region surrounding the handset when 3-bit phase shifters are used for analogue beam steering. Similarly, for the ACW two-handed grip, coverage was increased from 10.2% to 36.9% with 3-bit beam steering. Cumulative distribution function (CDF) performance for effective isotropic radiated power (EIRP) is also considered for the handset in free space, along with both grip orientations. It is once again shown that beam steering offers a significant performance increase; however, it is also shown that introducing the user's hand grip degrades the performance. Additionally, this paper investigates the impact of varying the phase shifter resolution used to actuate beam steering on the coverage of the handset. We found that increasing the resolution increases the number of possible steering angles at each array, thereby increasing the percentage coverage of the handset. However, we also note that the relationship between resolution and coverage plateaus around 3 bits. Overall, our study highlights the importance of beam steering in improving coverage and signal strength for handsets operating in the n257 frequency band. By exploring the impact of different hand grips and phase shifter resolution, we provide valuable insights into designing future handsets that can better serve users in various settings.

1. INTRODUCTION

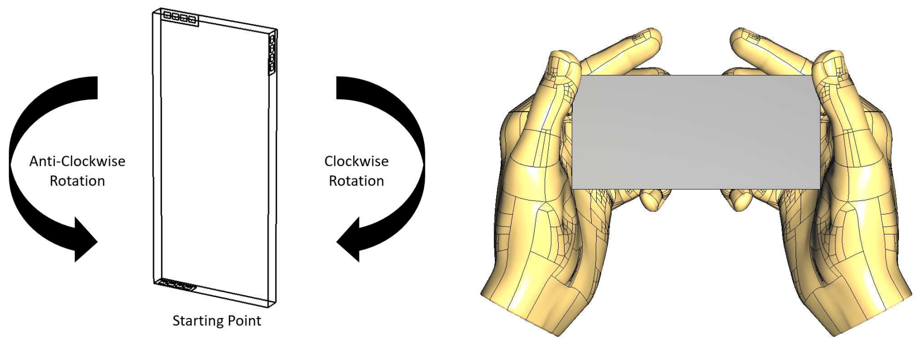
Wireless communication devices, like mobile phones, must have an omnidirectional radiation pattern in the communication frequency bands. However, achieving this pattern using multiple antenna elements is challenging at millimeter wave (mmWave) frequency bands for 5G (and likely for B5G), such as the n257 frequency band (26.5 GHz - 29.5 GHz), than at lower frequency bands [1].

This study extends previous work on quasi-omnidirectional handset coverage in the n257 frequency band using beam steering phased antenna arrays [2]. The effectiveness of a handset with these arrays in overcoming blockage posed by a human hand was determined through the use of various phase shifter resolutions to actuate beam steering in [3]. Other studies have explored the effects of grip patterns and grip-awareness models on handset coverage [5], as well as the effects of hand blockage on mmWave antennas and propagation [1, 5, 6]. Other investigations [7, 8] concentrated on the spherical coverage of user equipment at 28 GHz. However, these studies employed a different configuration of antenna array placements and did not provide information on the impact of using multi-bit phase shifters to vary the number of beam steering configurations.

Contribution –This investigation explores the impact of changing from a handset in free space to a two-handed grip on coverage area and the effect of beam steering on this performance using a rigorous simulation campaign, considering the holistic signal transmission and reception performance. Previous work [3, 4] has examined the impact of a right-handed grip and left-handed grip respectively on the findings of [2]. This paper aims to explore the impact of a two-handed grip.

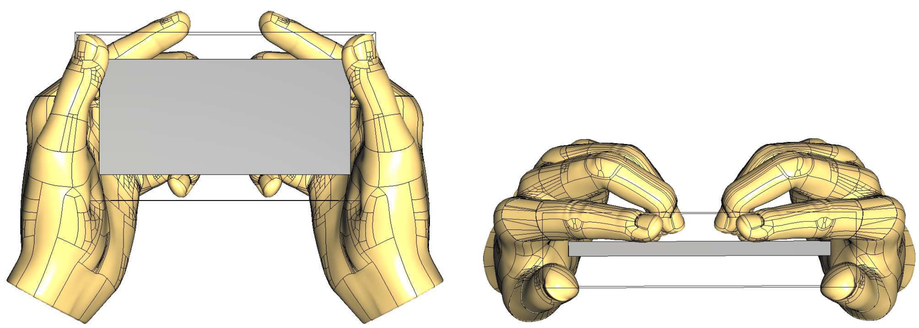
2. SIMULATION SETUP

The simulation involves two hand phantoms holding a mobile phone with 3 steerable antenna arrays. The grip scheme starts from a portrait position and considers both clockwise (CW) and anti-clockwise (ACW) orientations shown in Figure. 1 (a). The model of the two-hand phantom setup is depicted in Figure. 1 (b). The Finite-Difference Time-Domain (FDTD) method is used. To reduce simulation times due to hardware constraints, the bounding box is sized to include the main contact points of both hand phantoms, including the fingers and portions of the palm. However, the entirety of the hand is not included in the simulation to avoid significantly increasing the number of mesh cells and simulation time. The size of the bounding box is shown in Figure. 2. The handset is equipped with 3 antenna arrays, each of which has 4 elements. Each element is connected to a multi-bit phase shifter. In the specific case of a 3-bit phase shifter connected to each antenna element, 24 analogue beams have been considered, along with an additional beam with uniform excitation across all the elements and no phase shift. The number of beams increases as the phase shifter resolution increases.



(a) (b)

Figure 1: (a) Handset orientation (b) Handset grip scheme



(a) (b)

Figure 2: Two-handed grip setup showing bounding box from (a) front (b) top

3. BEAM STEERING

According to [2] and [3], the use of multi-bit phase shifters enabled beam steering to expand the coverage of each antenna array on the handset. One array was steered at a time, while the antennas of the unsteered arrays received in-phase signals. By using a 3-bit phase shifter (providing 8 steering directions per array), both clockwise (CW) and anti-clockwise (ACW) rotation coverage was obtained, as shown in Table 1. The ACW rotation had lower coverage compared to the CW rotation, with and without beam steering.

Scenario	No beam steering	3-bit beam steering
CW Rotation	19.7%	42.2%
ACW Rotation	10.2%	36.9%
No Hand	26.0%	61.1%

Table 1: Percentage coverage with gain greater than 0 dBi for various scenarios. *No Hand* results from [3].

It is required for handheld user equipment (UE) devices that operate in the n257 band to meet certain constraints as specified by the 3rd Generation Partnership Project (3GPP) in [9]. Specifically, they must have a minimum peak effective isotropic radiated power (EIRP) of 22.4 dBm, as well as a minimum EIRP of 11.5 dBm at the 50th percentile of the distribution of radiated

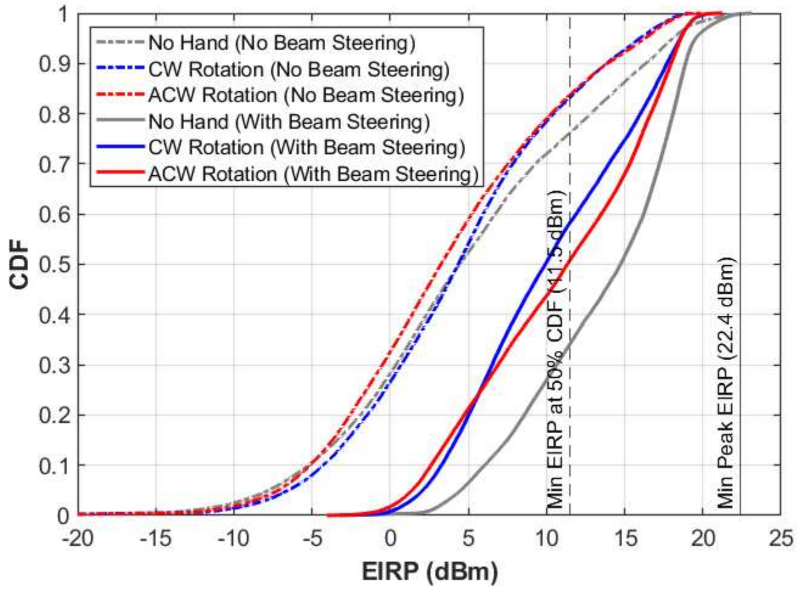


Figure 3: Comparison of CDF versus EIRP for various handset holding scenarios.

power. Using the '5G mmWave CDF + sPD' toolbox within CST, two cumulative distribution function (CDF) plots of EIRP were produced. One plot was generated by considering only uniform excitation of each antenna, while the other plot takes into account the total scan pattern when all beams (achievable with a 3-bit phase shifter as described in [3]) of each array are combined. In cases where one antenna array was used for beam steering, the other arrays were uniformly excited. The final results are shown in Figure. 3.

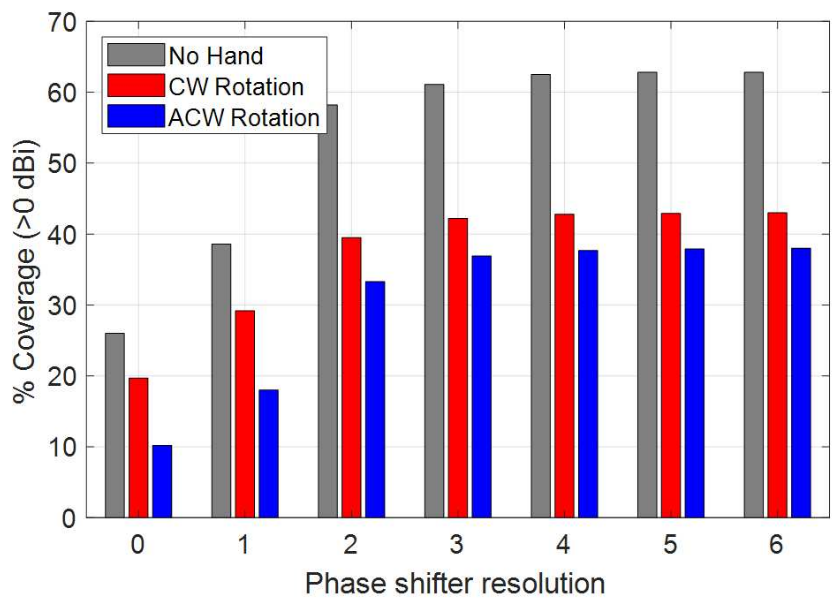


Figure 4: Comparison of percentage coverage of handset against phase shifter resolution. *No hand* data from [3].

The utilization of beam steering technology has been able to significantly increase the EIRP at the 50th percentile for both clockwise (CW) and anticlockwise (ACW) rotations. Specifically, it was observed that beam steering was able to increase the EIRP from 4.4 dBm to 9.9 dBm and from 3.3 dBm to 11.3 dBm for CW and ACW rotations, respectively. In terms of peak EIRP values, the CW rotation increased from 19.4 dBm to 21.1 dBm with the addition of beam steering. ACW rotation increased from 19.9 dBm to 21.2 dBm. Despite this significant improvement, it is important to note that beam steering was still unable to fully meet the 50% and peak EIRP targets established by the 3GPP for both CW and ACW rotations.

4. VARIATION IN PHASE SHIFTER BITS

This study examined how phase shifter resolution used to actuate beam steering affects the coverage region of a handset with three steerable antenna arrays. The findings, presented in Figure. 4, indicate that for each resolution, clockwise (CW) rotation provided better coverage than anti-clockwise (ACW) rotation. However, coverage without any hand present was better than either grip. In all cases, the coverage percentage began to plateau after 3 bits.

5. CONCLUSION

Based on these results, it can be concluded that although beam steering can significantly improve coverage performance for both grip schemes, the overall performance is still greatly affected by the hand position of the user due to suboptimal placement of the antenna arrays for the given grip scenarios. The study found that the CW rotation provided better coverage (where gain is greater than 0 dBi) than the ACW rotation. On the other hand, the ACW rotation grip yielded improved EIRP CDF performance when beam steering was implemented using 3-bit phase shifters. Increasing resolution of the multi-bit phase shifters increased the percentage coverage of the handset, but this relationship began to plateau beyond 3 bits.

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