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Quasi-Omnidirectional Millimetre Wave 5G Handset Antenna

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***Abstract*—This paper presents a handset antenna array that operates within approved millimetre-wave 5G (mmWave) 3GPP n257 band 26.5-29.5 GHz and provides quasi-omnidirectional radiation characteristics. The paper showcases a 4 x 1 linear antenna array that is placed into 3 distinct locations within a handset for testing against a numerical hand model which allows simulation of the effects of a user in a specific handset holding scenario. Blockages can cause significant degradation of the performance of the antenna, however, the optimized antenna locations presented in this work were capable of reasonable gain coverage with 52% coverage for gain values greater than 0 dBi. These results were achieved using a 3-bit phase shifter and have been verified by simulations, while single 4x1 array characteristics were confirmed by far-field measurements. Beam steering characteristics of these arrays are thoroughly investigated, showcasing how signal coverage can be improved in the event of a blockage. Study was also carried out into the effectiveness of increasing the size of multi-bit phase shifters and it is shown how this improvement is negligible beyond a certain point.**

***Index Terms*—antenna, array, coverage, handset, blockage, 5G**

I. Introduction

5G is currently being rolled out across the globe with implementation already happening in many major cities. It promises greatly improved data rates along with significantly more bandwidth over previous generations such as 4G [1]. However, this is not without its issues. One of the most common issues specifically with millimetre-wave (mmWave) 5G is the notable degradation in performance when the beam-forming is blocked by obstacles such as vehicles or buildings. A user's hand can also cause the similar degradation in a handset [2]. Focusing on acheiving quasi-omnidirectional coverage of the device under the influence of a user's hand is a scarcely documented problem. One study in particular [3] focused on the spherical coverage of the user equipment at 28 GHz, however this study made use of a different configuration of antenna array placements throughout and did not document the effects of varying the number of beam steering configurations through the use of multi-bit phase shifters. This work is an extension to our previous contribution in [4], with the introduction of a hand phantom. Comparisons between the handset in free space and in the presence of the hand phantom will be documented and beam steering will be carried out to showcase the improvement to the coverage performance that this can achieve. It will be demonstrated that while the gain can still be significantly reduced by blockages, this does not occur frequently, and the handset antenna proposed is practical for use in mmWave 5G applications.

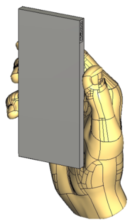


Fig. 1: Handset with numerical hand phantom.

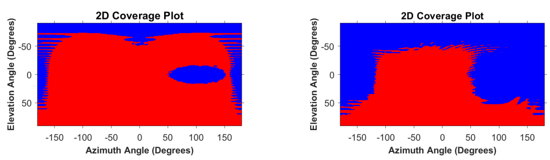
II. Handset Antenna Array

Antenna array design and placement within the handset will remain the same as in [4], as this was found to be the most optimal. So the handset will consist of a 4 x 1 linear antenna array placed along the right edge, bottom edge and back face of the handset. A hand phantom [10] is then introduced with dielectric properties at 28 GHz taken from [11] with and average of the wet and dry skin properties being used. The simulation setup can be seen Fig. 1.

III. Beam Steering Results

With the use of a 3-bit phase shifter allowing 8 beam steering configurations, coverage performance improved from 26% with no steering angles applied to 61% with all steering angles applied. Similarly, coverage with the hand phantom increased from 23% to 52% when beam steering was applied. These results show that the introduction of the hand phantom has reduced the overall coverage of the handset, when compared with the results in free space. The 2D coverage plots for the handset with the hand phantom can be seen in Fig. 2.

Cumulative Distribution Function (CDF) plot can be seen for the handset in Fig. 3. Minimum effective isotropic radiated power (EIRP) values have been set for handsets by 3GPP [12]. Handsets are classed as power class 3. These EIRP thresholds have been marked on Fig. 3. Beam steering has improved the performance in the scenarios both with and without the hand phantom. It can also be seen that introduction of the hand phantom reduces the performance for both the scenario with and without beam steering applied.



(a) (b)

Fig. 2: Simulated 2D coverage plots showing the coverage ¿ 0 dBi for the handset with hand phantom: (a) Without beam steering. (b) With beam steering. (Blue is areas covered, red is areas not covered.

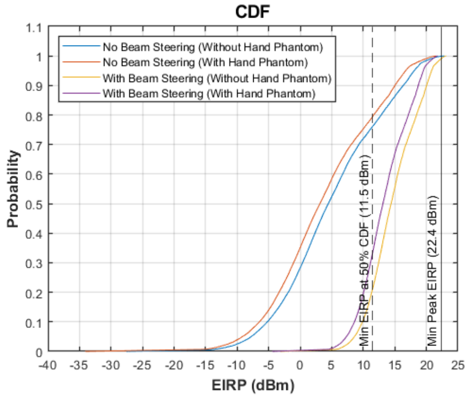


Fig. 3: CDF plot showing the handset without and with beam steering.

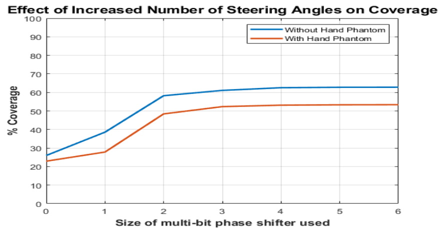


Fig. 4: Effect of increasing size of bit phase shifter on the coverage of the handset for realized gain values greater than 0 dBi.

IV. Impact of Hardware Extension

Increasing the size of the multi-bit phase shifter allows for an increased number of steering angle configurations. This increase will allow for a smaller phase step and in turn increases the number of available steering angle configurations along the selected range, r. Shown in Fig. 4 is a graph visualizing the effect on the coverage values that changing the size of the multi-bit phase shifter has.

V. Discussion

The results shown here show that beam steering can significantly improve the coverage provided. The impact of the number of phase shifter bits shows that beyond a 3-bit phase shifter that the improvement to coverage begins to plateau and the benefits are negligible. Throughout this paper a 3-bit phase shifter was used to generate 8 beam steering angles at each array. Using a 4-bit phase shifter yields 16 possible steering angles at each array, the resulting increase in percentage coverage was less than 2 percent for all the realized gain thresholds. Changing to a 2-bit phase shifter would still offer reasonable performance as the reduction in coverage percentage for all scenarios is only ≈ 4 percent, while still offering roughly double the coverage when compared with the handset with no steering angles applied.

VI. Array Operation Verification

The simulated antenna array used in previous sections was compared with a physical antenna array. Comparison of measured results with CST simulation results are given in Fig. 5. The differences between the experimental results and the simulations are minimal so it is reasonable to assume that full-scale array simulations with numerical hand-phantom will provides representative results.

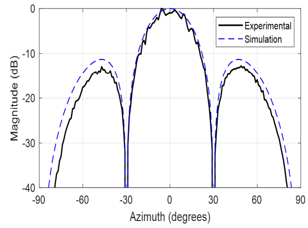


Fig. 5: Plot showing comparisons between the simulated antenna array against the physical array.

VII. Conclusion

In conclusion, a feasible antenna element and array design was laid out offering acceptable performance at 28 GHz. 3 of these arrays were then placed in the optimal positions around a handset and simulations were carried out to determine the coverage. Beam steering was then carried out on these arrays by means of phase shift and it was shown that these beam steering configurations allow for increased coverage. A hand phantom was then introduced, and it was shown that it reduced the overall coverage of the handset. It was shown that while coverage was improved by making use of the beam steering configurations, the current simulation set up is incapable of achieving quasi-omnidirectional coverage without further adjustments.

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