Wideband Wide-Scan Millimeter-Wave Phased Arrays for Enhanced Security/Privacy and Performance in 5G Mobile Wireless

Johnson J. H. Wang
Wang Electro-Opto Corporation
Marietta, Georgia USA
jjhwang@weo.com

***Abstract*— Millimeter wave (mmWave) phased arrays have been demonstrated recently as the technology that enables 5G mobile's grand vision of high data rate and low latency, as well as provides a physical layer security stemming from mmWave's high propagation loss in the air interface. This paper explores the fundamental issues in both capacity and security/privacy of 5G wireless, and proposes a solution to enhance its capacity and cyberspace security/privacy by employing wideband wide-scan mmWave phased arrays. Implementation on small mobile platforms such as smartphones and tablets is discussed.**

Keywords—5G mobile communication, secure communication, high data rate, data security, wideband wide-scan phased array, physical layer security, low latency

I. Introduction

Millimeter wave (mmWave) phased arrays have become a cornerstone for the grand visions of future wireless. In the case of 5G mobile, Samsung's demonstration using two 16-element arrays integrated into a smartphone at 28 GHz [1]-[2] was the pivotal event leading to a flurry of euphoric plans and projections.

However, wireless transmissions are inherently vulnerable to security breaches, and broadening the operating bandwidth would allow implementation of effective security measures [3]-[4]. Today, cyberspace hacking and security failures are frequent news, the vulnerability and limitations of cyberspace security are noted even by the general public. This paper explores the fundamental issues on 5G mobile, and proposes a solution to enhance both performance and security/privacy by employing wideband wide-scan mmWave phased arrays.

II. Rethink Relevant Mathematical Theories

The cyberspace is a man-made, virtual, notional, *digital* space, in which *the time t is a magic variable analogous to that in the physical space*. (Mathematical formulation of cyberspace invariably has been on the crutch of the theory on stochastic processes, which are focused on a set of real or complex time functions $\mathbf{x}(t,\zeta)$.)

When man began to venture into deep space (in the infinitely large distance) and the atomic structure (the infinitely small subspace), classical Newtonian physics had to be modified by tweaking the concept of time—by the theory of relativity and Hamilton-Jacobi equation in celestial mechanics for the former and by Schroedinger's equation in quantum mechanics for the latter.

The reign of classical digital communication theory over the Information Revolution has been over six decades. With the fundamentally changed global political-economic landscape, the requisite conditions and assumptions of information theory and their derivatives are increasingly more difficult to postulate. *It is time to rethink the magic dimension of time t in 5G, which aims at air latency of <1 msec and cell throughput of > 10 Gbps at mmWave frequencies.*

The phenomenal success of 4G gave rise to ubiquitous mobile connectivity, projected to reach 80 Billion devices in 2020. Therefore, the global cyberspace now has characteristics akin to biological systems. The air interface for each IoT (Internet of Things) is an open door, vulnerable to malicious and dubious penetration.

Although mmWave phased array can offer a physical layer security, yet its high propagation loss alone cannot guarantee sufficient signal-to-noise ratio needed to stop highly sophisticated players at all corners of the globe—or nearby. Air interfaces of wireless devices are fragile physical barriers akin to physical separation between biological systems.

III. Follow the Approaches in DAI

This author is taking a heuristic, yet practical, approach of following the steps taken in the global defense and aerospace industry (DAI). Since 1980, the U.S. has been developing software-defined radios (SDR), first under the SpeakEasy thrust around 1980, later transitioned to JTRS around 2000. In DAI, the security for a high-end wireless system mostly depends on its antenna, which ideally is broadband/multiband, has desired radiation patterns and polarization, and adaptive to deal with threat RF power or signal, etc.

For frequencies below 6 GHz, DAI has a newly produced Army AN/PRC-152A wideband network handheld radio covering most bands over 30-870 MHz, and a newer model covering six functions ranging from 30 MHz to 2000 MHz, in a contiguous way. Based on the principle of frequency scaling in electromagnetic theory, broadening the operating bandwidth and scan-angle at the air interface of the SDR with appropriate waveforms should be a logical approach for 5G mobile, as presented in [5]-[6].

IV. Preliminary Study on Solution for 5G

An empirical approach is taken to explore the feasibility of enhancing both performance and security/privacy by employing a mmWave phased array of wide bandwidth and wide scan angle, with practical implementation on small mobile platforms such as smartphones and tablets in mind [6]. Fig. 1 shows a preliminary scale model in which two thin subarrays are symmetrically positioned, and "integrated" into the surface of a generic platform. The subarrays' orientations about *Z*, the center axis of the platform, are varied, and aided by electronic beam steering, to attain full spatial coverage needed for the requirements.

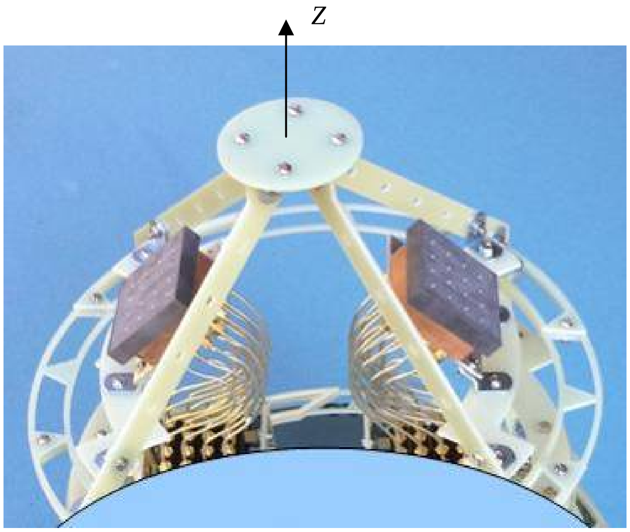

Fig. 1. A scaled generic model with two subarrays symmetrically positioned.

Each of these two subarrays is a 4×4-element planar array capable of very wide scan-gain bandwidth for wide scan (maximum 60° off each subarray's boresight). Each subarray is fed with True Time Delay (TTD) lines to steer its main beam from 0° (broadside or boresight) to 30° and 45°. ("Broadside" is the outward direction perpendicular to the planar surface of the subarray, not the *Z* axis.) Orientation of the two subarrays can be aligned mechanically so that they are conformal to the surface of a small platform, such as a smartphone or tablet, for easy integration.

Comparisons are made with the demonstration data in [1]-[2], in which two essentially 1-dimensional 16-element arrays of narrow bandwidth were integrated into a Samsung cellphone, where the patterns recorded and displayed appear to be in the plane of the smartphone surface, judging from the directivity and first sidelobe level of the pattern for 0° scan. Conceivably, the patterns on a plane perpendicular to the planar surface of the Samsung phone would have much lower gain and directivity. Thus the signal-to-noise ratio in this case might be considerably lower.

Fortunately, in indoor environments, multipath could significantly improve the antenna diversity gain sufficiently for the signal-to-noise required for the channel, which could be viewed as a massive MIMO mobile device at mmWave frequencies. However, a suitable deployment scenario appears necessary to deal with possible high LOS environments having virtually no multipath.

For the 2-D subarray in present study, its main beam can also be steered in the orthogonal plane or any other plane. (Perhaps only two rows as limited by the available space on a smartphone.) For the handset, a solution is to transmit in a pseudo-MIMO mode, and to perform signal processing in receive, in order to reduce the cost of beam forming.

Two highly promising low-cost RF beam forming technique are under study. Both approaches recognize the fact that costs of RF beamforming in Active Electronically Scanned Array (AESA) are costly, at least in the early stage of 5G. It is expected that, after initial success, in particular after user fear in security concerns subsided sufficiently, slightly augmented AESA can be applied to elevate 5G to a sustainable higher orbit than that currently advocated by many 5G leaders.

V. Concluding Remarks

Fundamental issues in the capacity and security/privacy in 5G mobile are examined. A practical solution is proposed, which could enhance both performance and security/privacy, based on employing wide-scan mmWave phased arrays of wide bandwidths. Their implementation on small mobile platforms such as smartphones and tablets appears feasible.

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