Wideband Antennas and Phased Arrays for Enhancing Cybersecurity in 5G Mobile Wireless

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***Abstract*— Fundamental issues on cyberspace and its security, in particular for 5G mobile wireless, are addressed from the concept of symmetric dual-space and dual-system. Formulated as a physical problem by narrowing "*Information*" to "*Electronic Information,*" and "*Communication*" to "*Telecommunication,*" with focus on "*Observables*," the current cyberspace is akin to a "*biological*" or "*intelligent*" system, and even vulnerable to *Chaos*. A practical solution to enhance both capacity and security/privacy is within reach by employing wideband diversity antenna systems, in particular wideband wide-scan mmWave phased arrays. Engineering, implementation, and business vision for this approach are discussed in the context of the ongoing pivotal and monumental global 5G mobile wireless thrust.**

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

I. Cybersecurity—Problem and Method of Attack

The cyberspace has been widely known as *man-made*, *virtual*, *notional*, *digital* space founded on classical *information theory*. As such, cybersecurity has been solely relying on cryptographic technology. Unfortunately, as hacking and security failures in cyberspace have grown rapidly to daily news, serious limitations of such approach become obvious.

As shown in the presentation of [1], global cyberspace is now akin to physical space that is "biological" or even highly "intelligent." (http://www.weo.com/Publications). It is noted that some fundamental axioms of the 70-year-old information theory are no longer valid for modern electromagnetic environment dominated by intense social political conflicts. For 5G Mobile Wireless, wideband antenna and phased array systems are proposed to enhance both capacity and security [1]-[3]. This paper provides further details and updates.

II. Dual Cyberspace and Physical Space

The present approach stems from the well established *dual-space/dual-system* concept in modern physics. One can formulate *information theory* as a *physical problem* by narrowing *information* to *electronic information*, and *communication* to *telecommunication*, with focus on *Observables*. (This restriction is not necessary, but bypasses formidable hurdles in a pedantic mathematical approach.)

Dual-space and dual-system formulations were instrumental in resolving some long-standing puzzles and mistakes in closely related problems. For example, errors in the equation of radiation from thin circular annular slot were discovered by comparing results between laborious direct derivation and invocation of duality [4]. As another example, accuracy of numerical computation on planar near field radiation by Fast Digital Fourier Transform was greatly improved [5].

While this approach is simple and straightforward, it seems to work only by using Field Equation (FE) and Fourier Transform (FT) at the level of dyadic integral with forms of *symmetry or parity*, as in [6]. *This requirement is actually rather difficult because "almost every English and American text" has taken the physicist's view of Faraday and overlooked the power of rigorous FE and FT with symmetric mathematical feature, as first pointed out by Stratton in Preface of [7]*.

As Stratton called—to no avail—that "*For an exploration of the fundamental content of Maxwell's equations one must again turn to the Continent,*" today the preface of a new text on advanced electromagnetics can still start with similar opening remarks "The pattern set nearly 150 [*sic*] years ago by Maxwell's *Treatise on Electricity and Magnetism* has had..."

III. Cybersecurity as a Physical-Space Problem

With focus on *Observables*, one can realistically formulate the transmission of electronic information as a physical problem of particle/wave packets that obey the laws of macroscopic electromagnetics and quantum mechanics, etc. For the wireless *channel*, *the RF front end of both transmit and receive systems are included*.

In quantum mechanics, each energy element E is proportional to its frequency ν given by $E = h\nu = 2\pi\nu\hbar$, where h *is* Planck's constant. Heisenberg uncertainty principle for a 1-dimensional wavepacket is given by

$$\Delta x \Delta p_x \geq \hbar; \qquad \Delta\theta\Delta p_\theta \geq \hbar; \qquad \Delta E \Delta t \geq \hbar;$$

where x, p_x, θ, p_θ, and t are the linear position, linear momentum, angle, angular momentum, and time, respectively. And the time-dependent Schroedinger equation with $\nabla^2\psi$ is similar to that in the wave equation of electromagnetic FE.

Taking cue of formulations in electromagnetics, quantum mechanics, and thermodynamics, relevant formulas in theories on information, communication, and signal processing can be derived in terms of time t, frequency f, energy E, *bandwidth* B, capacity *C*, and *entropy H*. For example, the Nyquist minimum *Bandwidth* requirement and the *Entropy* concept in electronic information can be characterized, especially for wireless, by its energy of the electromagnetic wave.

This approach can readily render the problem to a stochastic process expressed as a set of real or complex time functions $\mathbf{x}(t,\zeta)$ in which *the time t is a magic variable analogous to that in the physical space* [1]. However, as an intelligent physical space, the cyberspace is vulnerable to phenomena of *chaos*. The chaos as a deterministic event could rise from source singularity in the time domain or the corresponding spatial domain and frequency domain. Such reasoning would lead to the conclusion that wideband diversity antenna and wideband wide-scan mmWave phased array systems are needed for reliable cybersecurity.

IV. Engineering and Implementation Issues

The theoretical discussions so far in treating the cybersecurity as a physical problem are intuitively obvious to some, and have been practiced in the defense & aerospace industry (DAI). For example, 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 of a high-end wireless system fundamentally depends on its antenna, which ideally is broadband/multiband, has desired diversity in radiation patterns and adaptive to threat RF power, etc.

For frequencies below 6 GHz, DAI has produced, e.g., Army AN/PRC-152A wideband network handheld handset, as shown in Fig. 1. The newest model can cover six functions ranging from 30 MHz to 2000 MHz, in a contiguous way, as shown in Table I. For its antenna, a cost-effective breadboard Multi-band Body Wearable Antenna (MBWA) covering all functions has been developed and tested successfully [3]. MBWA's transitioning to 5G together with wideband wide-scan mmWave phased arrays is contemplated.

Fig. 1. Photo of Army AN/PRC-152A wideband network handheld handset.

TABLE I. Six Functions (Bands) Required for MBWA.

System served	Freq. (MHz)	Pol	Pattern	Sat/Ter	Tx/Rx
SINCGARS	30-88	LP	Omni	Terrestr	Tx/Rx
Air & Marine	116-174	LP	Omni	Terrestr	Tx/Rx
UHF Comm.	225-450	LP	Omni	Terrestr	Tx/Rx
UHF-Public Safety	450-512	LP	Omni	Terrestr	Tx/Rx
UHF SATCOM	225-318	RHCP	Hemisph	Satellite	Tx/Rx
L-Band (SRW)	1000-2000	LP	Omni	Terrestr	Tx/Rx

V. Business Issues

A. Regulatary issues

In late 2017, US FCC dismantled Net Neutrality regulations, thus removed regulatory barrier to broadband internet.

B. Cost/benefit Study

Presentation slides of [1] (http://www.weo/Publications) explained that huge cost reduction can be achieved by following the historical path of Flat Panel Display (FPD) in Electronic Viewing (slide #21), as shown in Fig. 2. Slide #22 showed that collective and competitive efforts on 5G should lead to success. This vision has gained traction as Foxconn later announced plans to invest $10 Billion in Wisconsin and $3 Billion in Michigan to build factories in 8K PFD and 5G smartphone. The details on cost/benefit study and other issues will be presented in the Symposium.

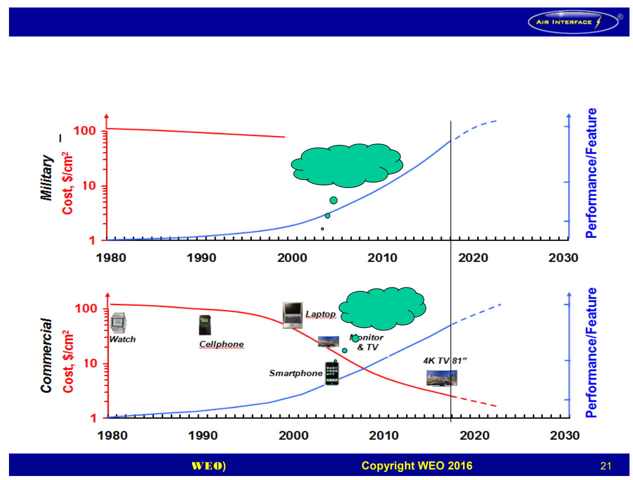

Fig. 2. Historical path of performance/cost-reduction in Flat Panel Display.

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