# Solving Cybersecurity Problem by Symmetric Dual-Space Formulation—Physical and Cybernetic

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***Abstract*—To address cybersecurity, this author proposed recently the approach of formulating it in *symmetric dual-space and dual-system*. This paper further explains this concept, beginning with *symmetric* Maxwell Equation (ME) and Fourier Transform (FT). The approach appears to be a powerful solution, with wide applications ranging from Electronic Warfare (EW) to 5G Mobile, etc.**

**Index Terms—cybersecurity, symmetric dual-space, Maxwell Equation, Fourier Transform, electronic warfare, 5G Mobile.**

## I. Introduction

Security problems in *both cybernetic and physical spaces* have suddenly and unexpectedly become top issues in daily lives. To address them and related issues accentuated in 5G Mobile, this author organized consecutive Special Sessions in IEEE APS-URSI Symposiums in 2017 and 2018 [1]-[2], in which he brought up a new—yet fairly established—approach based on formulating the cybersecurity problem in both spaces. This paper shows that this *dual-space/dual-system* approach is powerful—and even necessary as solutions in cyberspace alone is fundamentally defective.

## II. Symmetric Maxwell Equation (ME)

The original Maxwell Equation (ME) published in 1873 was bluntly criticized in Stratton's classical book in 1941 [3]. *Indeed, the original ME consisted of 20 equations with 12 unknowns; it was Oliver Heaviside who reduced it in 1890s to its modern form of four equations with four unknowns (**B**, **E**, **J**, ρ).*

Stratton's ME took the form of Heaviside—but *added magnetic current **J*** and magnetic charge ρ*.* In the time-space domain, algebraic **symmetry** of Stratton's ME was evident in the equations throughout the book, beginning on p. 25. In the frequency-space domain (in $e^{-i\omega t}$ convention), symmetric ME was displayed in a general form on p.464 in subsection 8.14, copy-pasted below as Eq. (1):

$$
\begin{array}{llll}
\text{(I)} & \nabla \times \mathbf{E} - i\omega\mu\mathbf{H} = -\mathbf{J}^*, & \text{(III)} & \nabla \cdot \mathbf{H} = \frac{1}{\mu}\rho^*, \\
\text{(II)} & \nabla \times \mathbf{H} + i\omega\epsilon\mathbf{E} = \mathbf{J}, & \text{(IV)} & \nabla \cdot \mathbf{E} = \frac{1}{\epsilon}\rho.
\end{array}
\qquad (1)
$$

*A terse comment immediately follows this equation: "The quantities **J*** and ρ* are fictitious densities of magnetic current and magnetic charge, which to the best of our knowledge have no physical existence." This terse comment appears to have fatally deterred adoption of Stratton's symmetric ME from 1960 to this date.*

Further examination revealed that subsection 8.14 had been written primarily by a then young post-doc Lan Jen Chu (fn. 1 on p. 464); *therefore this physicist's view was likely Chu's, not Stratton's.* After Chu took over Stratton's position at MIT in 1947 when Stratton moved up rapidly to higher positions, Chu's influence quickly grew globally with the rise of MIT. When Prof. Chu died in 1973, his young protégé Jin Au Kong "inherited" both Chu's position and views at MIT until he passed away in 2008.

## III. Symmetric Fourier Transforms and Dual-Space Dual-System Approach since 1940

As stated earlier, the *dual-space/dual-system* approach proposed by this author is not exactly a new one, but an established one. During 1940-1985, the generation and transmission of information using symmetric ME and FT formulated in *dual-space/dual-system* were heavily funded by US government and AT&T, as summarized below.

### *A. During 1940-1960*

As discussed in [2], *Stratton's Fourier Transform (FT) pairs also took symmetric algebraic forms,* as shown on p. 289 of [3], which are copy-pasted below as Eq. (2).

$$
\text{(21)} \qquad g(u) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{-iux}\, dx,
$$

and hence for $f(x)$ the reciprocal relation (2)

$$
\text{(22)} \qquad f(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} g(u) e^{iux}\, du.
$$

During 1940-1960 application of ***symmetric FT*** to mechanical waves achieved astounding success, as Blackman and Tukey described with excitement in the preface of their book [5]:

> "…we were able to discover....a very weak low-frequency peak which would surely have escaped our attention without spectral analysis. This peak, it turns out, is almost certainly due to a swell from the Indian Ocean, 10,000 miles distant. Physical dimensions are: 1 mm high, a kilometer long."

*This historic discovery of the magic power of spectral-space observation in contrast to the inadequacy of the physical-space observation heralded in the digital age.*

### *B. After 1960*

After 1960, expansion to telecommunications was accelerated, prompted not only by the monumental advance in acoustics just described but also by the availability of hardware and software that made digital computing increasingly lower in costs yet higher in performance. However, very strangely, in the open literature after 1960 symmetric ME and FT were replaced by asymmetric ME and FT; and the *dual-space/dual-system* was pursued only in the cyberspace.

*For an explanation, one might think the culprit was the US government maneuvering this change as part of its Cold War tactics, as their applications for the Defense and Aerospace Industry (DAI) were obvious. But this author noted that actually many textbook authors after 1960 were instrumental for the changes.* Adoption of asymmetric ME was explained earlier. Adoption of asymmetric FT was influenced by authors at Brooklyn Institute of Technology, which had risen to be the leading institution in microwave theory and technology during 1960-1980. *Their rationale for adopting asymmetric FT was "because it is commonly used in the engineering literature" as disclosed in a popular textbook published in 1962.*

## IV. Numerical Experimentation

This author was fortunate to arrive at Georgia Institute of Technology (GIT) in 1975, when a most advanced CDC Cyber-74 digital computer had just been installed. As no one on the campus was doing modern numerical analysis, use of this computer was open to him at nominal cost for more than five years. Such privileged and virtually unlimited use of a CDC Cyber-74 to solve ME problems in late 1970's was like exclusive use of the 17-mile-long particle collider to a physicist today. (Note that before 1990, as restricted by export control, high-performance digital computers were not available outside USA.)

Therefore, this author boldly pursued numerical experimentation on a wide range of electromagnetic problems formulated in *symmetric ME and FT pairs* while others—constrained by computational cost—*could not follow suits*. *It turned out that algebraic asymmetries in ME and FT could give rise to small errors. For example, equations for fields of magnetic dipole have been erroneous in textbooks for more than 50 years until this author uncovered them by invoking duality principle and also proved by the cumbersome direct derivation. As another example, while both GIT and NBS reported failure of FFT (Fast FT) algorithm for near fields from a source of circular aperture when nearing the source, data generated by this author were highly satisfactory.*

## V. Applications to Cybersecurity

We have shown that by formulating the cybersecurity problem in symmetric dual-space, as has been pursued in DAI communities since 1940, one can see that solutions in cyberspace alone have fundamental shortcomings and defects. *In particular, viewing in the spectral space, it is readily clear that broad bandwidth and real-time adaptation are the indispensable requisites for cybersecurity, which have been well known in DAI communities since late 1950s.*

(The problem is treated as a stochastic process focused on a set of real or complex time functions $\mathbf{x}(t,\zeta)$, where $t$ and $\zeta$ are both random numbers. Thus cybersecurity can also be viewed by the laws of Statistical Mechanics, Quantum Mechanics, Thermodynamics, etc.) *It can be stated that, as a rule, the broader the bandwidth (in both the channel bandwidth and operating bandwidth) and the faster the real-time adaptation are, the more robust the cybersecurity of the system is.* Indeed, it is obvious to seasoned engineers in DAI communities that a narrowband single channel system can be easily jammed, hacked, spoofed, monitored, and that its data stored or transmitted or received can be stolen or corrupted.

*This approach pervades any electromagnetic system, both wired and wireless, that has some electromagnetic intelligence and is not fully shielded electromagnetically*. Thus the discussions here are not limited to wireless systems; rather, they encompass any electromagnetic system that is not fully enclosed inside a closed surface layer S of thickness t sufficiently conducting and/or highly lossy, thicker than ¼ skin thickness $\delta$ [i.e., $t>\delta/(\lambda/4)$], thus can serve as a shield against penetration of electromagnetic energy over the entire electromagnetic spectra f of which the threat of concern is capable, where $f\times\lambda$=speed of light. *(Thus the discussions here are applicable to most wired electromagnetic system as well!)*

## VI. Experimentation

Experiments on broadband/multiband system with real-time adaptation for robust cybersecurity is being carried out for a wireless geolocation system and 5G Mobile for frequencies up to 40 GHz. The experiments are built on a wide range of mature broadband technologies developed at WEO. The findings so far are very promising, with the remaining technical challenge being development of broadband Rotman lens for beam switching [7].

## References


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