



DTIC DoDIAC Webinar 2023

Electromagnetic Spectrum Operations (EMSO) – What You Need to Know

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BLUF

Electronic warfare (EW) has evolved way beyond its original mission space...

The DoD needs a culture shift and a respect and appreciation for what it means to operate in the electromagnetic environment in the 21st century.



INTRODUCTION

Today's Agenda

- 1 The electromagnetic environment (EME) as a lexicon
- 2 What is the EME? What has changed?
- 3 Explanation of the electromagnetic spectrum and EMSO
- 4 Nexus of cyberspace and EMSO
- 5 What if...
- 6 Become an ambassador for EMSO in the DoD



A person in a field is shown in the background, wearing a jacket and holding a device. To their right is a large antenna array on a tripod. The entire scene is overlaid with a semi-transparent purple filter. The text is overlaid on the left side of the image.

The EME: Electromagnetic Environment as a Lexicon

We cannot keep calling it EW anymore...

What is a lexicon?

- Merriam-Webster defines a lexicon as:
“the vocabulary of a language, an individual speaker or group of speakers, or a subject”

“...lexicon can refer both to the vocabulary of a specific group of people...”

“...or to the general language used by an unspecified group of people”

- Prior to 1990, nobody used EME; nobody cared; most people didn't know it existed – they still do not, but...

Source: <https://www.merriam-webster.com/dictionary/lexicon>



*60 years ago, the EME was used by perhaps
100,000 people across the globe.*

One device per person.

Today it is used by over 6 billion people on the planet,
and by 2030, it is expected to be used by over 7.5
billion people, with an average of 10 devices.

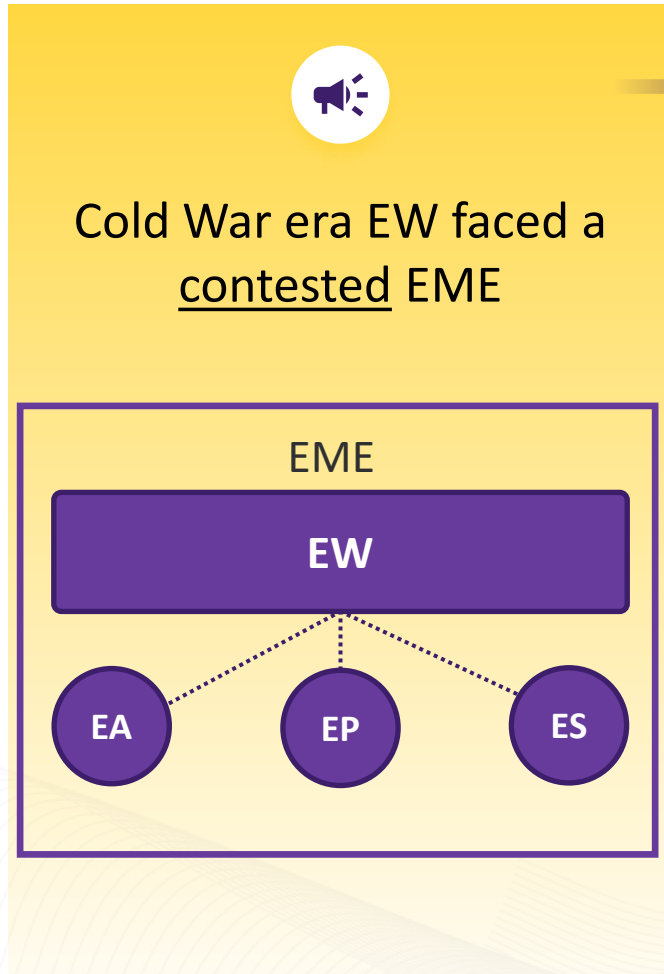
The EME is becoming a Social Public Good.

EME – Electromagnetic Environment

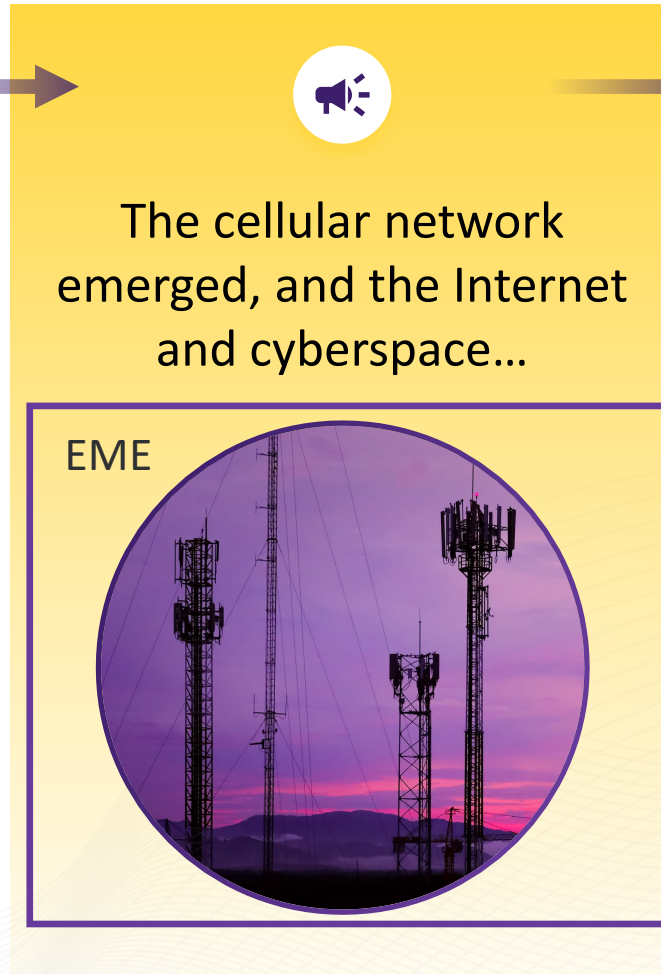
- It is all around us.
- Was there before the dawn of man.
- Not the same as EW, electromagnetic spectrum (EMS), or EMSO.
- It is electromagnetic waves “*radiating*” from various natural and (now) artificial sources.
 - Invisible electric and magnetic fields of force emanating in our physical environment
- It is the “physical layer” in the atmosphere.
- It is invisible, so most people on the planet do not know it exists...



What has changed?



1960s-1980s



1990s

Now the EME is congested as well

**Ensuring
electromagnetic
protect (EP)**

**is now part of a
much larger
environment...**

**A public commodity
– used by billions of
people**

2000s - Today

The EME

has now become a
large-scale collective action
problem (L-SCAP).

L-SCAP

Four characteristics of L-SCAPs

**Large Number
of Anonymous
Actors**

**Separated By
Large Distances**

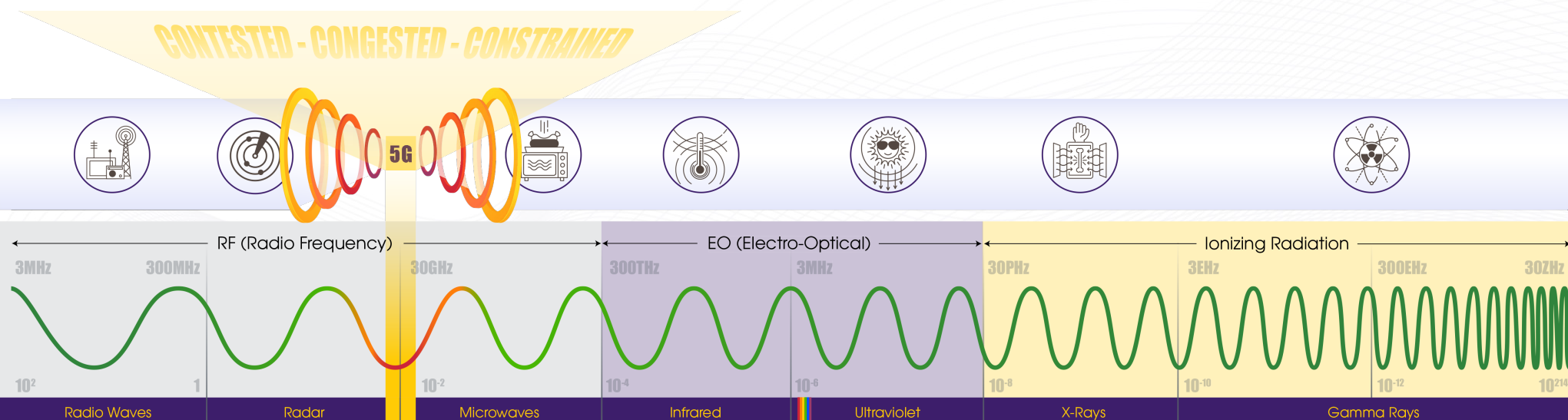
**Temporal
Displacement**

**Highly
Complex**

- Current policy and technological solutions for partitioning the EMS were not designed to handle 7.5 billion users.
 - Extraordinary social responsibilities now exist.
- The DoD cannot continue to treat the EMS as their own or as a static maneuver space independent of other users.

The EMS – Electromagnetic Spectrum

- The EMS is a tool and measurement technique used to designate quantized electromagnetic energy into a periodic unit of measure, called frequencies.
- It does not “exist,” per se; it is like a ruler in the atmosphere.
- As we create and manipulate EM energy, we force it into specific periodic waves.
- Frequencies have been sliced up and sold off based on the **Fourier Transform (FT) model**.
 - This model will not sustain the demand that is coming.
 - We will need a novel, dynamic, sharing solution for the entire EME *if everyone is going to use it as they wish.*



EMSO – Electromagnetic Spectrum Operations

- EMSO is the concept to represent what EW and spectrum management have become: $EMSO = EW + SM$
- $EW = EA + \text{EP} + ES$; $EMSO = EA + \text{EP} + ES + SM$
- The linchpin is EP = electromagnetic protect
 - EP = The ability and capability to access the EMS, despite congestion and contestation (e.g., jamming, degradation, spoofing)

Lexicon



EW could never be done without EP, but now assured EP is in jeopardy, not just from adversaries, but from 7.5 billion users.

Nexus of Cyberspace and EMSO

- Cyberspace is a maneuver space, part of the information domain.
- EMSO is a maneuver space, too, but...
- The EMS is the transport layer for cyber data (1s and 0s).
- Cyber data cannot flow without access to the EMS (unless the data remains hardwired).



So, both spaces depend on EP, and EP is now part of a much larger realm of concern.

- EA and ES also cannot operate without access to the EMS.
- Access to the spectrum is NOT assured for cyber or EMSO, EMBM, JADC2, MDO.
- Plans need to coalesce - policy and doctrine need to change.



WHAT if....

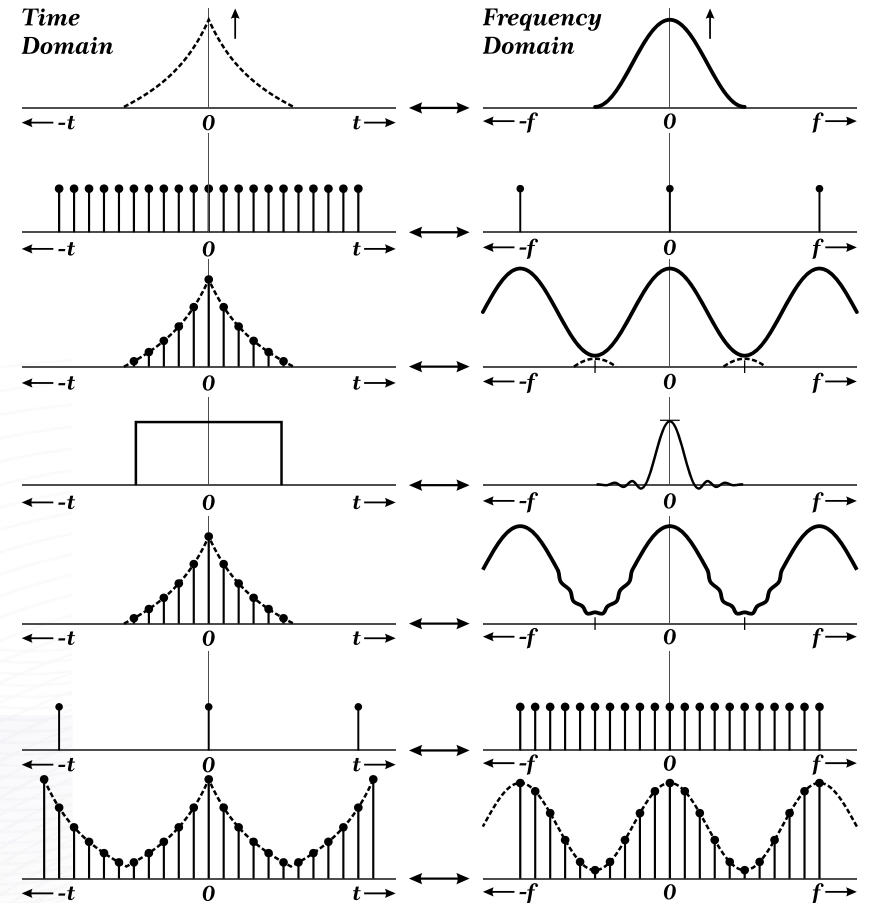


Slicing up the EMS – The Fourier Transform

$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{j\omega t} dt$$

→ Why do you suppose the FT became the standard for carving up the spectrum?

1. Early (1811) mathematical standard, easy to promulgate across the globe
2. Time domain = multiplication; frequency domain = convolution → easier!
3. Linear computing (1950s) → easy to code infinite sums (integrals)
4. Constant power, periodic sinusoids – easy to model and estimate



With improvements in processing power and sophisticated algorithms, a disruptive opportunity has emerged...

HERE'S AN IDEA...

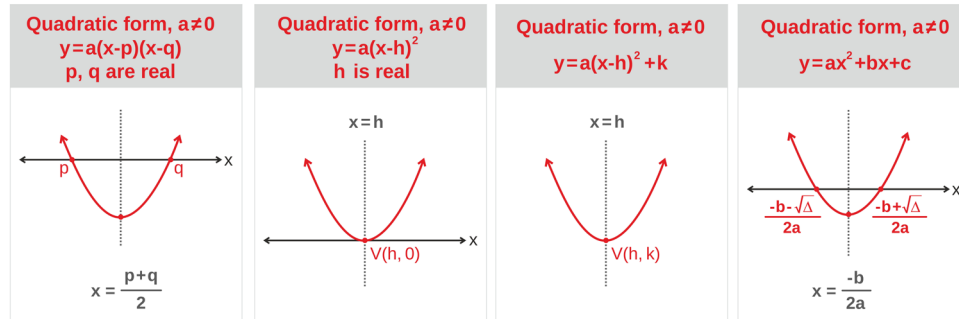
Why not model signals of interest with a non-constant, a-periodic sinusoidal waveform?

Polynomials!

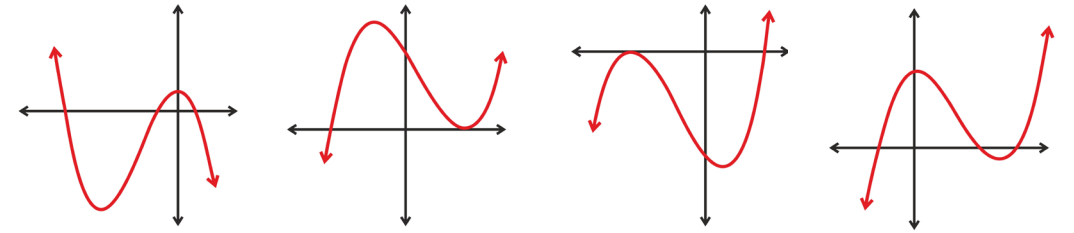
$$x^4 + 3x^3 + 8x^2 + 1 = 0$$

Polynomial Functions

Quadratic Form



Cubic Functions



Roots & Coefficients

Quadratics
 $ax^2 + bx + c = 0$

$$\alpha + \beta = -\frac{b}{a}$$

$$\alpha\beta = \frac{c}{a}$$

Cubics
 $ax^3 + bx^2 + cx + d = 0$

$$\alpha + \beta + \gamma = -\frac{b}{a}$$

$$\alpha\beta + \alpha\gamma + \beta\gamma = \frac{c}{a}$$

$$\alpha\beta\gamma = -\frac{d}{a}$$

Quartics
 $ax^4 + bx^3 + cx^2 + dx + e = 0$

$$\alpha + \beta + \gamma + \delta = -\frac{b}{a}$$

$$\alpha\beta + \alpha\gamma + \alpha\delta + \beta\gamma + \beta\delta + \gamma\delta = \frac{c}{a}$$

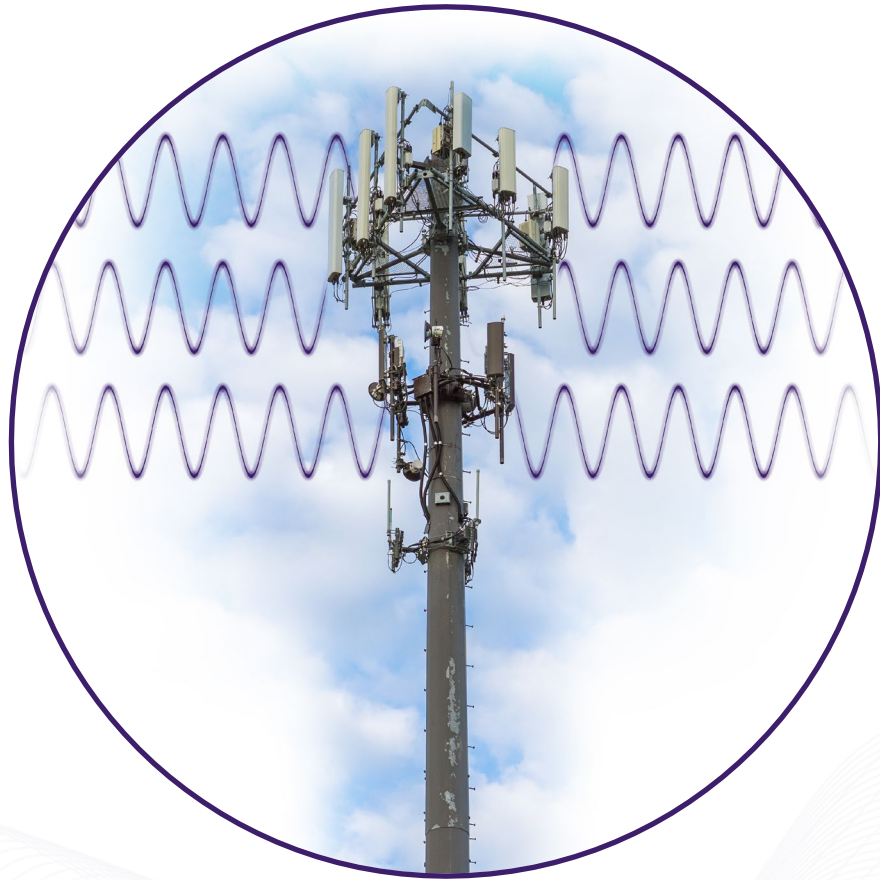
$$\alpha\beta\gamma + \alpha\beta\delta + \alpha\gamma\delta + \beta\gamma\delta = -\frac{d}{a}$$

$$\alpha\beta\gamma\delta = \frac{e}{a}$$

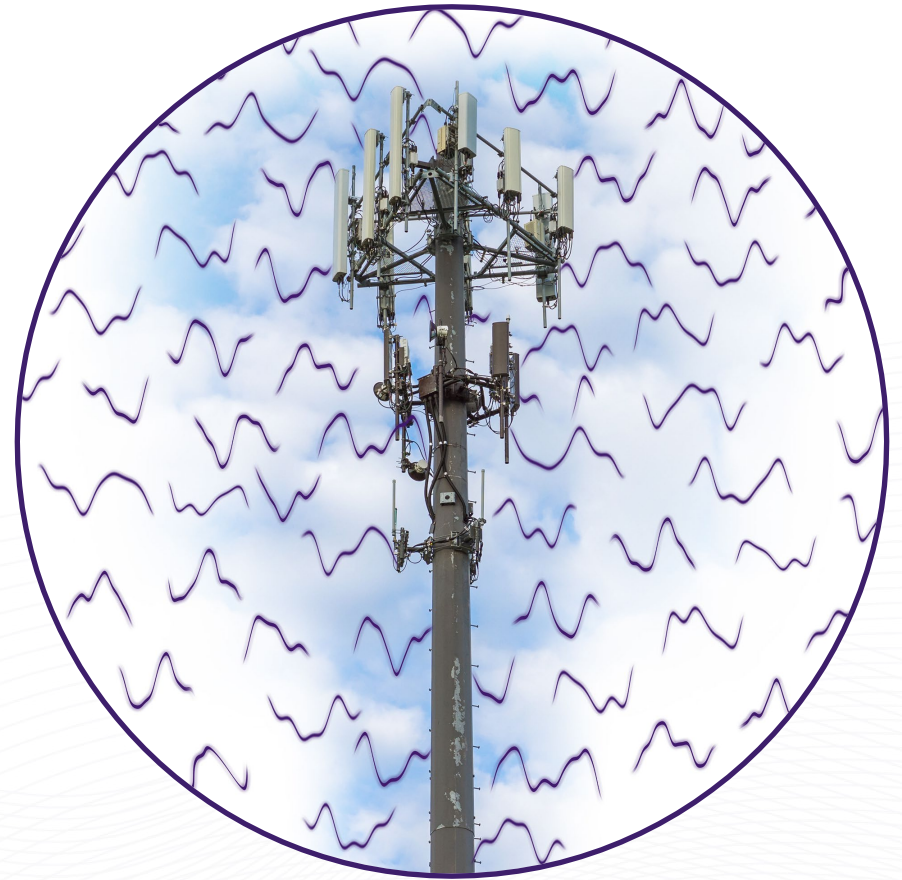
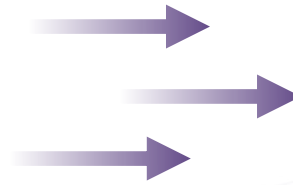
Quartic Polynomial Equation

$$ax^4 + bx^3 + cx^2 + dx + e = 0$$

What would a non-stationary spectrum look like?



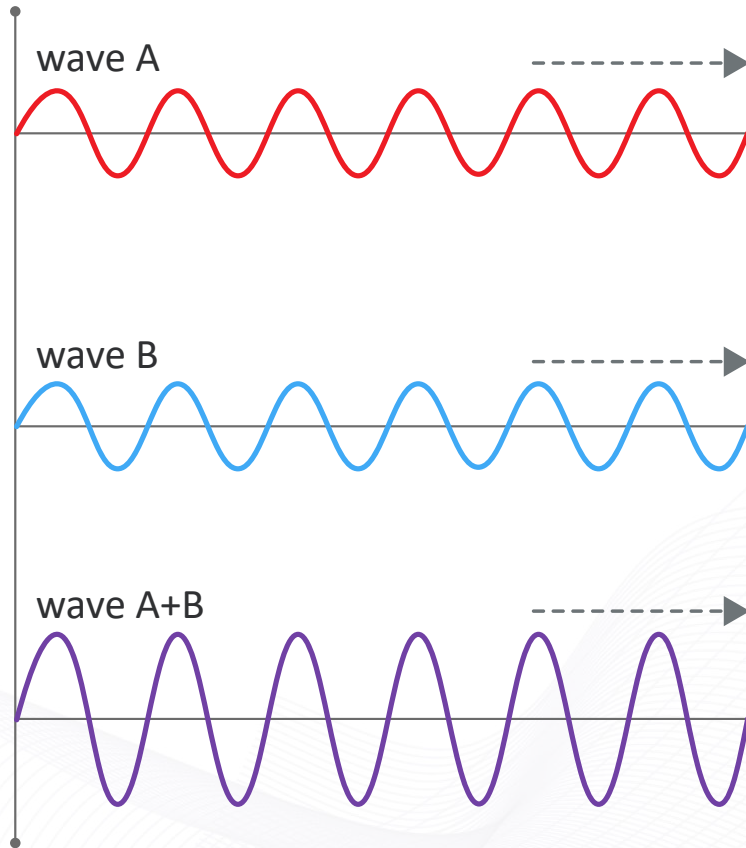
Instead of a bunch of these...



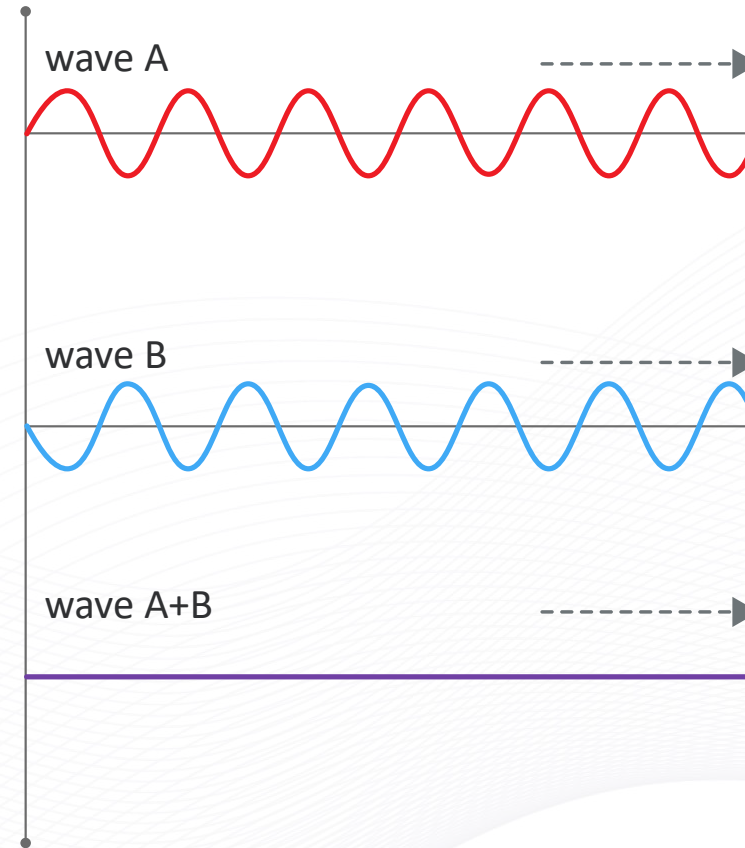
Many more of these!

Periodic Waves – Wave Interference

constructive interference



destructive interference



Polynomial Waveforms: A Non-stationary Electromagnetic Spectrum

- Modeling the EMS as non-stationary proposes many benefits:
 - ✓ Low power
 - ✓ MUCH increased capacity
 - ✓ Utilizes the energy available in the spectrum more efficiently
 - ✓ High security without added complexity or processing power
 - ✓ For military uses, highly unexpected and virtually undetectable
 - ✓ LPI/LPD
 - ✓ No ownership of frequencies



Challenge:

The entire EMS model is based on the stationary
FT spectrum

BUT! Remodeling the EMS with non-stationary waveforms is a *disruptive change* that may be needed...

Pythagorean Theorem:

If two teenagers can
change 2000 years'
worth of mathematics...

Then this, too, can be done!

Become an ambassador for information dominance

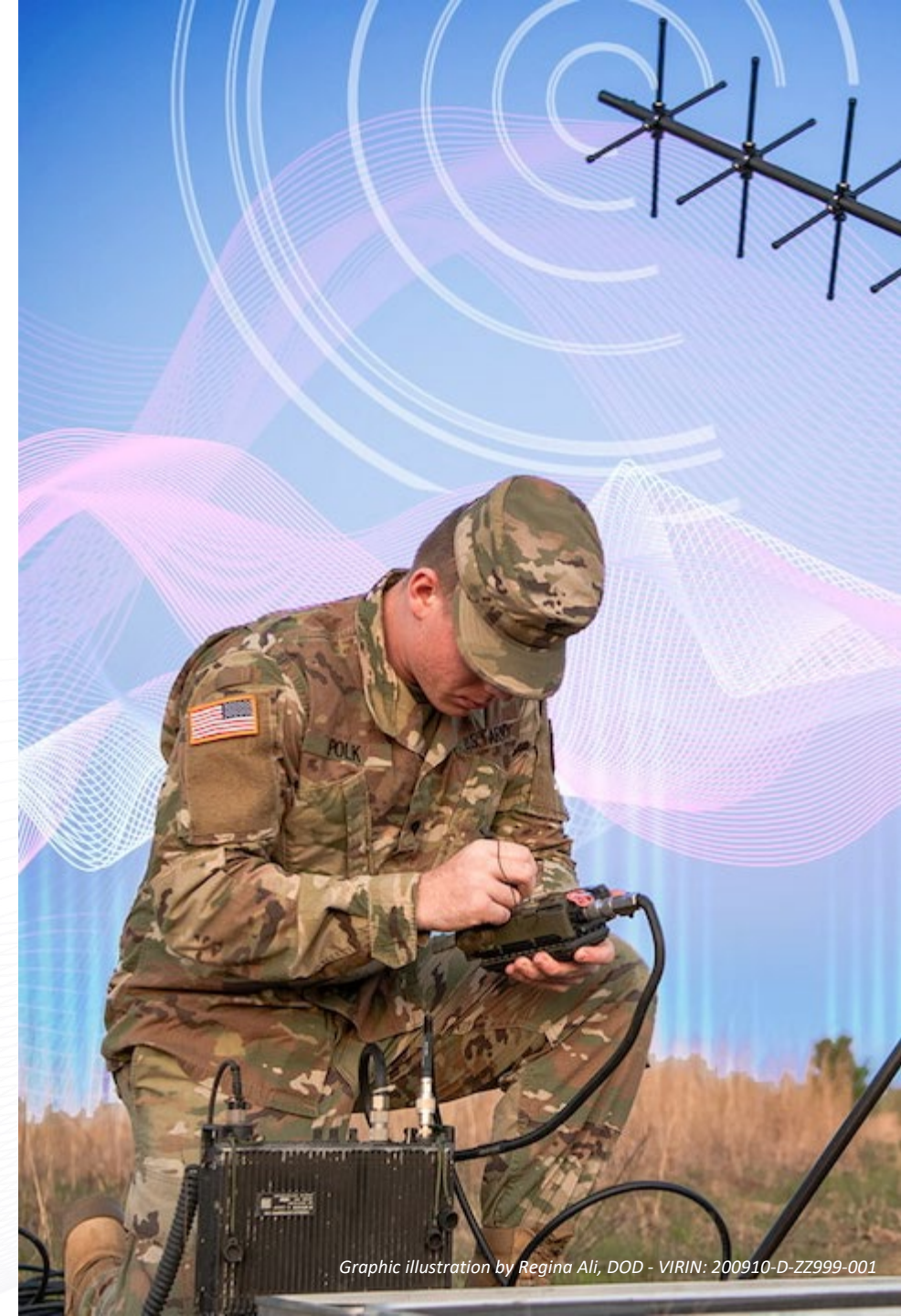
- When working in any information domain space (cyberspace, EMSO, EMBM, JADC2) ask:
 - “What are we doing to ensure our access to the EMS? And have we conferred on that plan with others? With the local communities, where do we intend to use it?”
- Promote collaborative discussion, question policy
- Test to ensure access to the EMS is being addressed on every *spectrum-dependent system*



What needs to happen now?

1. Start using the lexicon: EMSO.
 - This changes the focus to systems-of-systems thinking for EMSO, the EMS.
2. EP capabilities need to be made a top priority = funding, requirements, procurement.
3. The DoD EMSO community needs your ideas for dynamic spectrum access/spectrum sharing.

Plans made to access the EMS must be made with consideration for all users of the EMS.



RVJ Institute – promoting EMSO excellence for the DoD



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THANK YOU!