Health Matters

New ICEMAN Project Seeks Answers to Fighter Pilot Disorientation

■ **James C. Lin**

In August 2020, the U.S. Defense Advanced Research Projects Agency (DARPA) issued an invitation for the submission of innovative research proposals related to its Impact of Cockpit Electro-Magnetics on Aircrew Neurology (ICEMAN) project that could lead to a better understanding of this phenomenon. ("Iceman" happens to be the war name of a fighter pilot played in the movie *Top Gun*).

In its request for proposal (RFP) [1], DARPA stated that, "Current cockpits are flooded with radio frequency (RF) noise from on-board emissions, communication links, and navigation electronics, including strong electromagnetic (EM) fields from audio headsets and helmet tracking technologies." The stated objectives are to determine whether the current air combat cockpit EM environment may impact cognitive performance and/or physiological sensor performance as well as to quantify the effects and demonstrate potential mitigation strategies.

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Military pilots often report cognitive performance challenges during flight operations. Many have reported experiences with spatial disorientation (SD), in which the pilot's perception of aircraft position, motion, altitude, or attitude does not correspond to reality [2]–[5]. SD has posed a significant problem to military pilots and continues to be a challenge today. These reports indicate that SD mishaps occur in fighter/attack aircraft at more than five times the rate of nonfighter/attack fixed-wing aircraft. Indeed, the rate of SD-related accidents is estimated to be 11–12% of military aircraft crashes [3], [4].

The number of SD accidents at night is higher than at daytime. Visual illusions at night because of the degraded visual environment are well documented. During night flights, pilots sometimes confuse ground lights with stars and unlighted areas of the Earth as night sky.

From 1993 to 2013, SD accounted for 72 Class A mishaps, 101 deaths, and 65 aircraft lost in U.S. Air Force flights [5]. Mishaps are defined as Class A if they result in death or permanent total disability or destruction of aircraft. It is noteworthy that mishap rates for F-16 fighter/attack aircraft were found to be marginally higher than for other fighter/attack aircraft.

SD may be caused by several human factors, such as the visual, vestibular, and somatosensory systems involved in cognitive performance. Aside from the potential effects on cognitive functions and human brainwaves already mentioned in the DARPA announcement, there may be potential responses of a more abrupt and distractive nature resulting from exposure to high-power pulsed RF and microwave radiation.

The DARPA RFP mentions that the cockpits are flooded with RF signals from onboard emissions, communication links, and navigation electronics, including strong EM fields from audio headsets and helmet tracking technologies. It has been hypothesized that the cockpit RF and EM fields, especially the frequencies between 9 kHz and 1 GHz, may influence cognitive performance, including SD, task saturation, and misprioritization. However, RF and EM fields in cockpits are not currently monitored; little effort has been made to shield pilots from these fields, and the potential impacts of these fields on a pilot's cognition have not been assessed.

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It is reasonable to assume that fighter cockpits are subjected to strong impinging RF and/or microwave radar pulses under some operational conditions. Common characteristics of these radar pulses are high peak power (gigawatts), short pulsewidth (microseconds), and fast pulse rise time (nanoseconds). Depending on the specific materials and designs of the helmets, RF and microwave radiation could penetrate and reverberate inside a pilot's helmet and head to generate even higher RF and EM fields within the head under these circumstances.

The resulting exposure to high-power pulsed RF radiation and associated microwave energy deposition in head tissues may not produce overt tissue heating but can elicit sensitive biological responses. The prime examples include microwave pulse-induced acoustic pressure waves in the head (microwave auditory effect) [6], [7] and the startle reflex and motor reaction behaviors observed in laboratory animals [8]–[10]. Indeed, there may be similarities among these pulsed microwave-induced responses. The microwave auditory effect has been implicated in the Cuba sonic attacks on diplomats [7]. However, as discussed later, the microwave power threshold needed for startle reflex and motor reaction is higher than that required to induce the microwave auditory effect. Indeed, the microwave auditory effect may be the cause for the startle reaction resulting from a much louder microwave-induced sound. Thus, it is plausible that an unexpected, sudden, and intense auditory stimulus inside the head from a high-power radar could elicit a classic acoustic startle reflex that can cause abrupt changes in the pilot's head position, orientation, or attention.

The startle reflex and motor reaction behaviors are innate responses of mammals to an unexpected and sudden occurrence, such as an intense auditory, visual, or somatosensory (tactile) stimulus that interrupts ongoing behavior, distracts from attentional function, initiates actions, and prepares the individual against a potential threat. Concurrently, it activates a protective stance to prevent injury and may alert the person or animal to instigate evasive behaviors [11], [12].

For 1.25-GHz microwave radar pulses (10 μs, 80 Hz), the threshold for startle reflex was found to be 0.29 kJ/kg. The microwave energy was associated with a lower than 0.1 °C potential rise in the bulk tissue temperature in mice [8]. Clearly, the response is not associated with microwave-induced tissue heating. Furthermore, it has been shown that a single 1.25-GHz microwave pulse (0.8–1 μs) to the head of rats at 22–43 mJ/kg per pulse [peak specific absorption rate (SAR), 23–48 kW/kg] could modify the acoustic startle response [13]. In another investigation, 1.25-GHz microwave pulses averaging 0.96-μs wide and 35.5–86-kW/kg peak SAR (66.6–141.8 mJ/kg of absorbed energy) were reported to modify the startle response in rats [9].

In summary, the ambient RF–EM field levels in a typical fighter/attack aircraft's cockpit are now unclear. Quantitative surveys and measurements are necessary to allow the proper assessment of the RF–EM field's potential effects on pilots' brain activity, neurophysiology, and behavioral responses. Noticeably, fighter cockpits are subjected to strong impinging RF and/or microwave radar pulses under some operational conditions.

There are two pulsed microwave-induced auditory responses in humans and mammals when the head is exposed to high-power microwave pulses that could impact a pilot's cognitive performance and response. Both are related to microwave pulse-induced acoustic pressure waves in the head: the microwave auditory effect and the acoustically induced startle reflex and motor reaction from a sudden, unexpected, intense auditory stimulus. The startle reaction from a sudden, unexpected auditory stimulus may cause the pilot to experience SD, during which one's perception of aircraft position, motion, altitude, or attitude does not correspond to actuality.

Note that this supposition is derived from theoretic treatment along with available but limited experimental evidence. The kinds of confirmational studies that would be useful are neurophysiological and psychophysical investigations of pulsed microwave-exposed animals, including observations of the subjects' behavioral and performance responses.

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President's Column *(continued from page 10)*

MTT Community

Credit goes to Jim Rautio for being the first to suggest "MHz To THz Community" as the MTT-S tagline. Significantly, Jim pointed out to the MTT-S AdCom at our summer meeting in May 2016 the meanings of the word *community*:

1) a group of people having a particular characteristic in common
2) a feeling of fellowship with others as a result of sharing common attitudes, interests, and goals.

It was both the second meaning of community and the fact that MHz To THz can be abbreviated to MTT that sealed the deal for our MTT-S tagline. Thanks, Jim!

Before the selection of this tagline, quite a few AdCom members resisted having any tagline at all. After all, the MTT-S had existed for more than 60 years without one. Yet, once "MHz To THz Community" was selected, it was fully embraced by all AdCom members. The tagline is indeed compelling.

History of the MTT-S Magic Tee Logo

The other part of our MTT-S branding is the magic tee logo. The *IEEE Group on Microwave Theory and Techniques (G-MTT) Newsletter* was first published on 10 September 1954. Some 15 years later, the newsletter announced the G-MTT symbol contest. Numerous entries were received, and the one getting the most votes came from Raymond A. Patrin, with Robert E. Putre's magic tee coming in a close second [1].

Ultimately, legal (trademark) conflicts with the IEEE kite logo made Patrin's entry unfeasible, and so Putre's design was the winning logo. Thus, the now-famous magic tee motif became the official MTT-S logo, appearing on the cover of the newsletter in October 1970. Since that time, the logo has taken on great meaning and become a source of pride throughout the Society and among its members.

What is a magic tee? It is a 180° hybrid power divider implemented using a tuned four-port waveguide, originally developed during World War II and first reported in a publication by W.A. Tyrrell of Bell Labs [2]. The magic comes from the way it prevents signals from propagating between certain ports under specific matching conditions. This allows it to be used as a duplexer; e.g., in a radar system, it can be used to isolate the transmitter and receiver while sharing the antenna.

I would like to acknowledge Sherry Hess and Ramesh Gupta of our AdCom Marketing and Communications Committee for capturing all of the elements of our current MTT-S branding in detail. The newly released *The MTT-S Brand–IEEE MTT-S Brand Book* [3] describes the use of the MTT-S brand elements and is consistent with the IEEE branding guidelines.

The MTT-S is a very active IEEE Society. I encourage you to visit our website, www.mtt.org, for more information. If you would like to be involved as a volunteer, fill out a contact form at www.mtt.org/connectme, and we will make sure you get connected.

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