Millimeter-wave Research at NRL in the IoT Age*

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Seventy years ago, J. R. Pierce noted: "*The millimeter wave range, a relatively undeveloped field for research, presents a challenge to theoreticians, experimentalists, and inventors alike . . .*"[1] It may have taken awhile, but theoreticians, experimentalists, and inventors took up the challenge, and are developing the millimeter wave range for a myriad of commercial and military applications. The vision for a future where everything is interconnected is placing a tremendous burden on the available channel capacity to transmit all of the information that must be exchanged between nodes in a networked world. Traditional RF and microwave frequencies do not offer the channel capacity required to exchange this information.

This is a fundamental problem for both the commercial vision of the IoT where all automobiles, toasters, refrigerators, tablets, phones, etc. are connected, but also for the military's vision of the future battlefield where every soldier, sailor, unmanned system, etc. is interconnected. The vision is basically the same: everything will be interconnected (within privacy and security constraints). The millimeter wave spectrum offers a potentially vast increase in channel capacity, enabling the exchange of data these networked systems require. Many technical challenges remain, however, including obvious challenges such as the power, efficiency, and sensitivity of millimeter wave components, as well as approaches to managing and analyzing the information generated. Additionally, military systems face some additional challenges, such as the need to respond in real-time to disruptions to clearly defined spectral allocations, but potentially enjoy some advantages, too, such as LPI/LPD of highly directional compact antennas.

The development of a commercial IoT millimeter wave technology base adds to the military challenge as the proliferation of such technology provides a fundamental technology base for the development of military capabilities. The Navy is developing the technologies needed to address these challenges, from the development of efficient high-power millimeter wave sources based on vacuum electronics, wide-bandgap, and ultra-wide-bandgap semiconductors, to adaptive and reconfigurable systems employing novel materials and architectures, to efficient low-power consumption non-Von Neuman computational architectures.

[1] **J. R. Pierce**, **"**Millimeter waves*,*" *Physics Today, vol. 3, no. 11, pp. 24-29 (Nov. 1950).*
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