Foundations of a career in industrial microwave engineering

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Early years

The day I joined the Microwave Applications Research Centre (MARC) — the commercial arm of the University of Wollongong — remains unforgettable. It was 25 July 1988, the day my first son Joel was born. Fittingly, Joel has now worked alongside me in microwave technology for more than eighteen years. At the time, I was a young engineer only two years into my career, stepping into a field that would shape the next several decades of my life.

Those early years were electrifying. For more than a decade, I genuinely looked forward to Mondays. I devoured every book and paper I could find on microwave science, often reading the best ones twice. My mentor, Professor Frank Paoloni — whose experience included high-temperature plasma research at Princeton University — was instrumental in my development. I spent countless hours in his office wrestling with concepts that pushed the boundaries of modern thermal processing.

Being an Australian engineer often meant feeling isolated from the large global community of microwave researchers. To bridge that gap, I attended every AMPERE and IMPI conference possible. These meetings were invaluable: an opportunity to learn from world leaders, exchange ideas, and enjoy a brief holiday while doing it.

Our early work at MARC centred on pyro-metallurgical extraction — an enormously challenging area led by one of Australia's most respected scientists, Professor Howard Warner. In hindsight, few fields are more complex to commercialise than high-temperature (above 1200 °C) extractive metallurgy. It has taken me nearly three decades to feel confident navigating its technical, thermal, and operational risks.

Over time, my enthusiasm for mastering the underlying physics and engineering made me an essential contributor to MARC's research portfolio. After roughly fifteen years, I presented a proposal to the University that ultimately led to the creation of Advanced Microwave Technologies Pty Ltd (AMT). Under that agreement, I became an Honorary Academic Fellow, acquired the assets and intellectual property of MARC, and in return committed to ongoing theoretical and practical support for university microwave projects, including supervision of students.

By the time AMT was formed in 2001, MARC had already completed commercial programs across Australia, New Zealand, South Africa, Italy and the Czech Republic. Yet there remained a clear global need for an organisation capable of bridging academic insight with commercially ambitious, entrepreneur-driven industrial scale-up. AMT was established precisely to fill that gap — and it continues to do so today.

Key Principles for Scaling High-Temperature Microwave Processes

1. Frequency Selection

Microwave energy absorption ($P_v = 2\pi f\varepsilon_0\varepsilon''E^2$) increases with frequency. However, commercial viability depends on source efficiency, waveguide dimensions, penetration depth, and capital cost per kW. The frequency of 915 MHz typically offers deeper penetration and lower cost, making it ideal for industrial scale-up.

2. Power Density & Field Uniformity

High temperatures amplify non-uniform field risks — hotspots, plasma formation, thermal runaway.

Stable industrial systems depend on uniform volumetric power distribution.

3. Temperature-Dependent Dielectric Behaviour
Material properties ε′ and ε″ change significantly with temperature and phase transitions, sometimes abruptly. Predictive modelling must account for thermal runaway risks and structural transformations.

4. Thermal Management & Refractory Engineering
Above ~1000 °C, radiative losses dominate, refractories influence field patterns, and metals such as stainless steel become lossy. Proper refractory selection and thermal design are essential.

5. Modularity, Control Systems & Safety
Microwave systems at high temperature must operate within stable coupling windows. Modular reactor designs allow safe scaling: each module maintains controlled power density while enabling increased throughput.

Current High-Temperature Projects (Past Two Years)

1. Spodumene Calcination — 1000–1100 °C
2. Alumina (Al_2O_3) Calcination — 1000–1200 °C
3. Asbestos Thermal Inactivation — 800–1000 °C
4. Zinc Fuming from EAF Dust — 1000–1300 °C
5. Microwave Plasma Applicator Development — >1400 °C.

Closing Reflection
From a young engineer in 1988 to the founder of AMT, the journey has been shaped by curiosity, persistence, and a determination to master one of the most complex thermal technologies in modern industry. AMT continues to bridge research breakthroughs with commercial applications worldwide.

About the author

David McLean is a senior engineer and director of Advanced Microwave Technologies, based in Wollongong, Australia, with more than four decades of experience in high-power industrial microwave systems. He holds a Bachelor of Electrical Engineering from the University of Wollongong and has worked across research, consulting, and industrial deployment, including roles at the University of Wollongong's Microwave Applications Research Centre and Illawarra Technology Corporation. His career has focused on translating microwave science into robust, scalable industrial solutions across minerals processing, waste treatment, food manufacturing, textiles, and industrial chemistry. He is internationally recognised for developing and commercialising novel microwave processes, with major projects spanning PFAS soil remediation, asbestos treatment, microwave pyrolysis, rare-earth mineral processing, zero-emissions waste systems, and reversible animal stunning. McLean has authored numerous peer-reviewed papers presented at leading international conferences and is a named inventor on multiple patents covering environmental remediation, food processing, materials treatment, and electromagnetic applicator design. He is an active member of global microwave industry bodies, including AMPERE and the International Microwave Power Institute, and continues to work at the forefront of industrial microwave scale-up and applied innovation.