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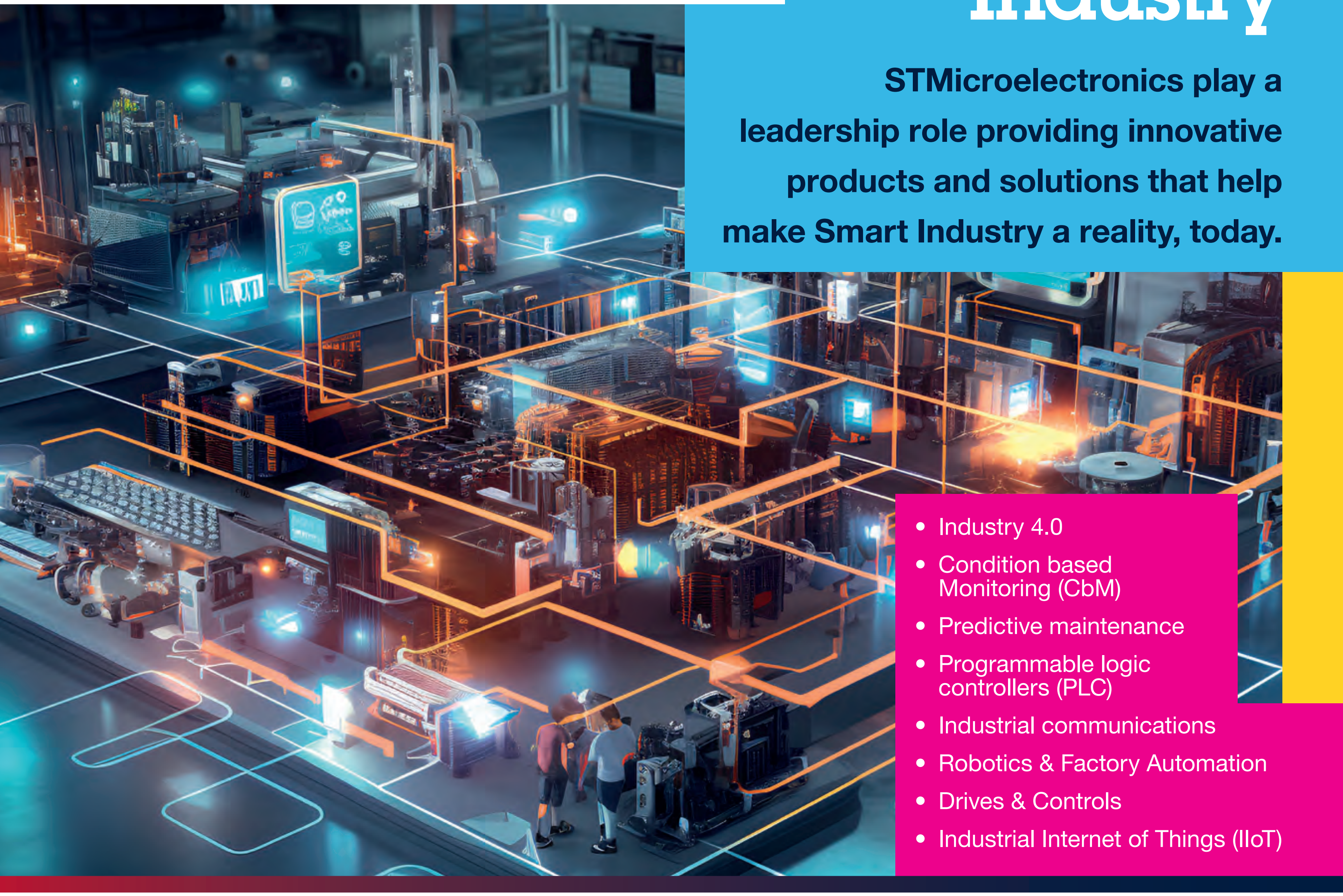


Time to Bridge the Terahertz **Gap**

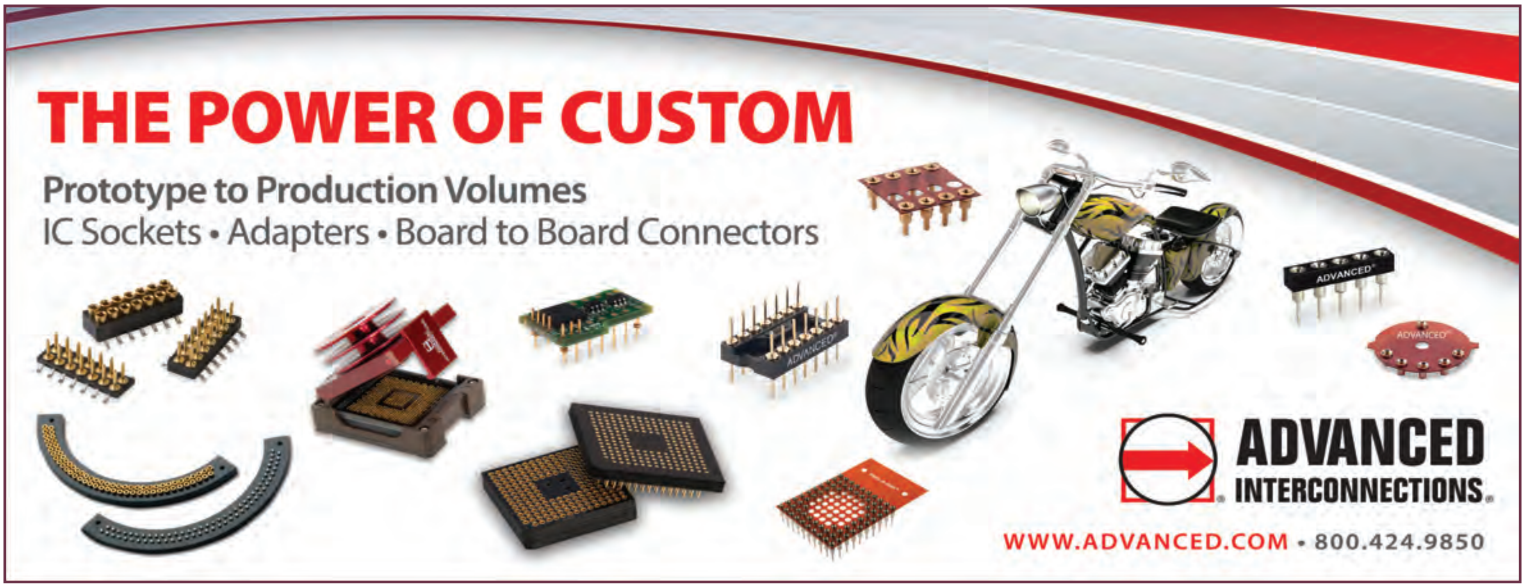
Researchers at **IMRA** turn to THz-capable components in pursuit of a molecular clock that can more accurately measure time, down to the second.

The scientific community is striving to bring life to the so-called "dead zone", a region of the electromagnetic (EM) spectrum between electronics and optics. This band, often referred to as the "terahertz gap", resides between 100 GHz and 30 THz. Below it lies the microwave bands that are increasingly being consumed by numerous commercial and scientific applications. Above it, infrared devices like thermal imaging, night vision equipment, and fiber-optic transmission and data storage are now common.

Within the terahertz technology gap lies a vast reserve of bandwidth poised for development. However, the development of user-friendly technologies capable of generating, manipulating, and detecting radiation within these frequency bands is not only technically challenging but has also been hindered by the limitations of available THz-capable components.

IMRA, was able to overcome many of the issues associated with the THz regime recently when working at frequencies above 300 GHz. Researchers at the Colorado-based laboratory were looking to use molecules as stable frequency references that could potentially be used as clocks.

"Let me be clear, we are not redefining the definition of a second," explains Research Scientist James Greenberg, a program



manager at IMRA. "The definition of the second is always going to be a laboratory experiment that's very complex, but there are many reasons why you do need a practical implementation to more accurately measure a second."

While it may seem esoteric to be concerned about the accuracy of a second, several future industries stand to benefit from this functional research; a noteworthy one includes space travel.

Motivating the move

"Future space navigation will benefit from this type of research," adds Greenberg. "You can't use GPS in space because there is no "G" in your global positioning system. So, if you want to know where you are, you need extremely good inertial sensors and timekeeping."

While space travel is provocative and exciting, the urgency to bridge this terahertz gap is currently being driven by numerous other, more terrestrial, applications. For example, the development of 6G wireless communication and beyond.

"The carrier frequency of 300 GHz is 150 times larger than two gigahertz where the current cellular network is today," explains Greenberg. "So, take the number of devices we currently have and imagine multiplying that by a factor of 150. That's the biggest driver in going into a higher frequency."

Other industries that stand to benefit from better utilisation of the THz band include radio astronomy, GPS navigation systems, navigating in areas where GPS is unavailable like underwater, caves, mines.

Another breakthrough will include terahertz radar which will provide the missing link between traditional radar and lidar; Light Detection and Ranging. For example, lidar can see objects much smaller than radar, but cannot see through clouds. Terahertz radar can perform better than lidar in inclement weather while improving the angular resolution of traditional radar. It is also complimentary to both radar and lidar in that some materials exhibit different opacities in the different spectral ranges.

IMRA research

During their research of alternatives to the current state-of-the-art optical atomic clocks operating at several hundreds of terahertz, IMRA researchers encountered the common issue of standing waves, also referred to as signal reflections or mismatches. These undesirable waves, or ripples, can attenuate power output, distort the information on the carrier and, in extreme cases, damage internal components.

To alleviate the problem of standing waves at lower microwave frequencies, engineers rely on Faraday rotation isolators, more commonly referred to simply as isolators. At their very basic level, an isolator is a two-port, input and output, component that allows EM signals to pass in one direction, but absorbs them in the opposite direction. The problem is that traditional isolators fail to deliver at higher frequencies within the THz regime.

IMRA was working at hundreds of gigahertz to interrogate molecules, which naturally rotate at a very specific frequency. A molecule will only absorb radiation when it is identical to the frequency at which it is rotating. The challenge for researchers is to efficiently reach frequencies within the terahertz band, where the majority of small molecules rotate.

Instead of multiplying microwaves up, which is most common, IMRA researchers used a photonic oscillator to divide lasers down using dissipative Kerr soliton (DKS) microcombs.

By generating a 301.442 gigahertz wave the researchers were able to talk to nitrous oxide (N_2O) molecules in a vacuum chamber where they were isolated. However, reflected waves would have interfered with the signal, delivering sub-optimal results. Therefore, Greenberg and his team decided to insert an MMW isolator that worked within the WR 3.4 band (220 GHz - 325 GHz) into the waveguide.

"We actually had a WR 3.4 band isolator from Micro Harmonics on the shelf from past research projects," explains Greenberg. "We plugged it in and got fantastic results."

Under a NASA awarded contract, Micro Harmonics Corporation designed an advanced line of MMW isolators capable of optimal operation between WR-28 and WR-2.8 (26.5 GHz to 400 GHz). The commercial off-the-shelf (COTS) components offered IMRA the high isolation, low insertion loss and small footprint it was looking for.

THz Components

"High isolation was extremely important, and we were getting 30 dB of isolation with the isolators," adds Greenberg. "We were also starved for power because our transmitter was weak, and we were really pleased with the low insertion loss the isolator provided which allowed us to get the maximum signal to noise."

For molecular spectroscopists and people who work with clocks, tiny effects have huge implications, namely for GPS. For example, the difference between parts per million and parts per billion is the difference between having GPS and not.

"If you can't do better than a part per billion, you can't have GPS," adds Greenberg. "It just doesn't work."

Since the initial experiment, IMRA has moved on to study other molecules in its research.

"The Micro Harmonics isolators also have a really wide band which allows us to look at a range of molecules at different frequencies using the same spectrometer as previous experiment with the exact same isolator," says Greenberg.

The pursuit of a molecular clock

Atomic clocks all work the same way. There is an oscillator operating at a specific frequency and the key is to stabilise that frequency to an atomic reference, something that will not change no matter where or when you look at it. An atom, for example, is going to react the exact same way anywhere on Earth as well as in space.

While the cesium atom remains the industry standard, the world's first atomic clock actually used a molecule (Ammonia NH_3).

www.MicroHarmonics.com.