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Marconi Inspires Rice University Design for 1-terabit Wireless

Researchers will use pulse-radio technology to speed wireless data rates

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This silicon-germanium chip converts a digital trigger to a 5-picosecond pulse of radiation with a frequency spectrum exceeding 1 terahertz. The chip supports a repetition rate up to 10 gigahertz, provides beam-steering capability and contains a two-by-four array of transmitters with antennas that can each be independently programmed with resolution steps of 300 femtoseconds. (Photo by Jeff Fitlow/Rice University)

Rice University wireless researchers are taking a page from radio inventor Guglielmo Marconi to create the first laser-free, wireless system capable of delivering 1 terabit of data per second.



Rice University engineering researchers Aydin Babakhani (left) and Edward Knightly are taking a page from the radio inventor Guglielmo Marconi to create the first laser-free, wireless system capable of delivering 1 terabit of data per second. (Photo by Jeff Fitlow/Rice University)

Such a [speed](#) would be more than 20,000 times faster than today's [top 4G wireless](#) networks and about 20 times faster than the U.S.' [speediest home internet](#) services. A terabit is 1 trillion bits of information. A 1 terabit-per-second signal could simultaneously stream about 200,000 [high-definition movies](#).

"Breaking the terabit-per-second barrier with radio will enable an entirely new set of wireless applications and communication paradigms," said [Edward Knightly](#), professor and chair of Rice's Department of Electrical and Computer [Engineering](#) and principal investigator on a new \$1.3 million, three-year grant from the National [Science Foundation \(NSF\)](#) to develop terabit wireless [technology](#).

The need for such [speed](#) is indicated by a [2016 Cisco study](#) that found [global](#) mobile data traffic grew by 74 percent in 2015, rising to 3.7 [exabytes](#) (almost 30 million terabits) per month in December 2015. The same report found that smartphone data usage grew 43 percent in 2015, with the average user consuming 929 megabytes per month. That was driven in large part by the public's rapidly growing appetite for watching videos on mobile devices. Cisco found that mobile video accounted for 55 percent of all mobile data traffic in 2015.

That level of demand led the [NSF](#) to invest more than \$60 million in radio spectrum research over the past five years. The grant to Rice

is part of a new \$11 million round of investment announced by NSF today.

To hit the 1 terabit-per-second threshold, Knightly and co-principal investigator [Aydin Babakhani](#) plan to use pulse-based radio [technology](#). That represents a break with the carrier-wave modulation technology that wireless companies have relied on for decades. Babakhani, assistant professor of electrical and [computer](#) engineering at Rice, said pulse-based technology is probably the only laser-free wireless technology that can support data rates in the 1-terabit-per-second range over a single channel, but his team must clear a number of hurdles to [demonstrate](#) that they can both send and receive 1 trillion high-frequency radio pulses per second.

“Pulse-based technology isn’t new,” Babakhani said. “Marconi first demonstrated it in the early 1900s. He used an antenna connected to a large capacitor. By charging that, he could cause the power to [build](#) up until the voltage difference ionized the air gap and caused all the power to be sent to the antenna at once. That was the first pulse-based communication network. He used it to show he could transmit long distances, and it was low-frequency.



Aydin Babakhani

“Our pulse-based system is inspired by Marconi’s invention, but instead of the power going to a large antenna through an air gap, like Marconi’s, ours goes to an on-chip antenna through a high-speed bipolar [transistor](#),” he said. “We’re storing [magnetic](#) energy on the chip, and then using a simple [digital](#) trigger to release that. Once released, it radiates as a picosecond impulse. There is no oscillator: It’s direct [digital](#)-to-impulse radiation. Unlike laser-based pulse systems, which can send even shorter pulses, ours can send many pulses very fast, which translates to a high pulse-rate frequency, something that’s vital for achieving the data speeds we are targeting.”

Babakhani’s lab, which set a world record earlier this year for transmitting the shortest radio pulse of 1.9 picoseconds, will develop and [fabricate](#) a dinner-plate-sized transmitter that can send even shorter pulses at high frequencies ranging from 100 gigahertz to several terahertz. The transmitter will actually contain about 10,000 individual antennas, each of which is a separate microchip capable of sending out picosecond radio pulses. Babakhani said the number of antennas will [boost](#) the signal strength, making it possible to [demonstrate](#) the technology over distances up to a quarter mile. In addition, the antenna array also will allow the team to steer the signal with fine accuracy.



Edward Knightly

“Modulated, frequency-based communications technology has been perfect for the lower frequency radio [waves](#) that we have relied on over the past half-century, but everything changes at higher frequencies above 100 gigahertz,” Knightly said. “Instead of having signals that bounce off walls and are highly scattered throughout the environment, we’re moving to a regime where we only effectively have line-of-sight. The benefit is we’re going to blast all the bandwidth and all the information directly to a device with laser-sharp focus, and no one else will be able to intercept that signal because any receiver that’s offline simply won’t [detect](#) it. So, we’re focusing like a laser but we’re using radio. The challenge is to steer that beam to the right place at the right time and to follow users as they move.”

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