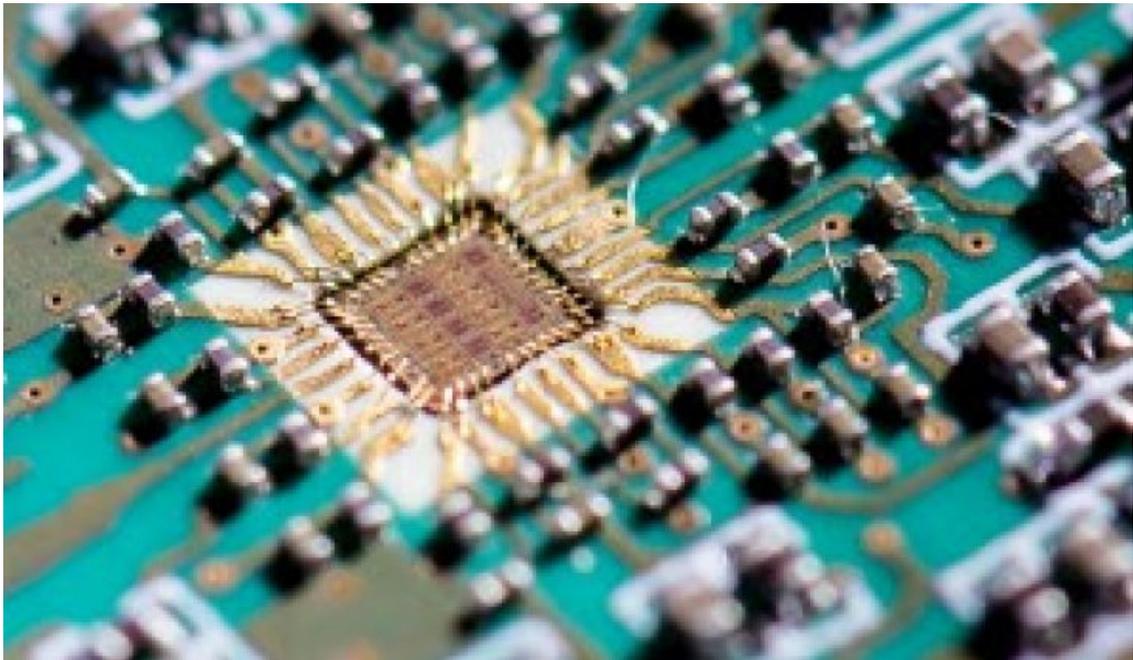


## Pulse-radio technology design for 1-terabit wireless

brian wang | October 12, 2016



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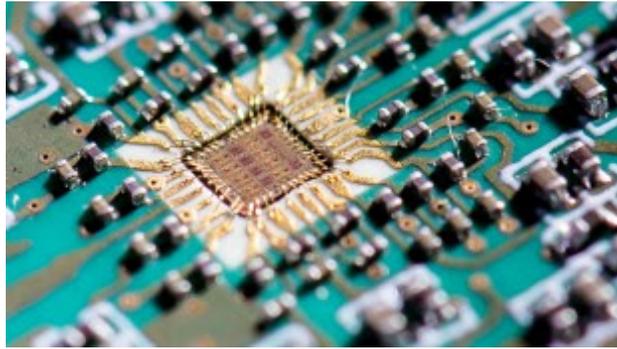
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Rice University wireless researchers are taking a page from radio inventor Guglielmo Marconi to create the first laser-free, wireless system capable of delivering 1 terabit of data per second.

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.



*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 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)*

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.

“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.

“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.”

SOURCES – Rice University



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## Update on the Liquid Fluoride Thorium Reactor projects in China and the USA



[The Liquid Fluoride Thorium Reactor is a type of Molten Salt Reactor.](#) Molten Salt Reactors are Generation IV nuclear fission reactors that use molten salt as either the primary reactor coolant or as the fuel itself; they trace their origin to a series of experiments directed by Alvin Weinberg at Oak Ridge National Laboratory in the '50s and '60s. The LFTR is differentiated from other variants of the MSR by the fact that it runs on thorium rather than uranium, thorium being an element that is fertile rather than fissile, and which will transmute to fissile uranium-233 upon exposure to neutrons.

In 2011 the Chinese Academy of Sciences announced plans to commercialize a thorium-based MSR in 20 years (it is also developing non-thorium MSRs and solid fuel thorium reactors). The Shanghai Institute of Applied Physics has since employed 700 nuclear engineers for this project. The plan is for a 10MW pilot LFTR is expected to be operationalized in 2025, with a 100MW version set to follow in 2035.

China theoretically has enough thorium to supply all its energy for the next 20,000 years.

[Shanghai Institute of Applied Physics \(SINAP, under the Academy\) has two streams of TMSR development – solid fuel \(TRISO in pebbles or prisms/blocks\) with once-through fuel cycle, and liquid fuel \(dissolved in FLiBe coolant\) with reprocessing and recycle.](#) A third stream of fast reactors to consume actinides from LWRs is planned.

The TMSR-SF stream has only partial utilization of thorium, relying on some breeding as with U-238, and needing fissile uranium input as well. SINAP aims at a 2 MW pilot plant (TMSR-SF1) initially, and a 100 MWt experimental pebble bed plant (TMSR-SF2) with open fuel cycle by about 2025, then a 1 GW demonstration plant (TMSR-SF3) by 2030. TRISO particles will be with both low-enriched uranium and thorium, separately.

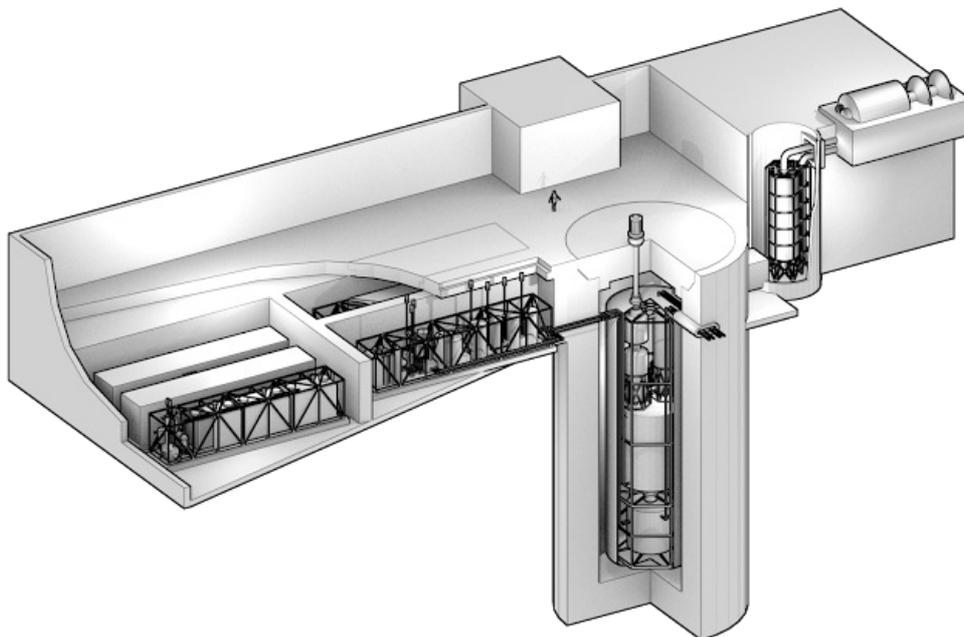
The TMSR-LF stream claims full closed Th-U fuel cycle with breeding of U-233 and much better sustainability with thorium but greater technical difficulty. SINAP aims for a 2 MWt pilot plant (TMSR-LF1) by 2018, a 10 MWt experimental reactor (TMSR-LF2) by 2025 and a 100 MWt demonstration plant (TMSR-LF3) with full electrometallurgical reprocessing by 2035, followed by 1 a GW demonstration plant. A TMSFR-LF fast reactor optimized for burning minor actinides is to follow.

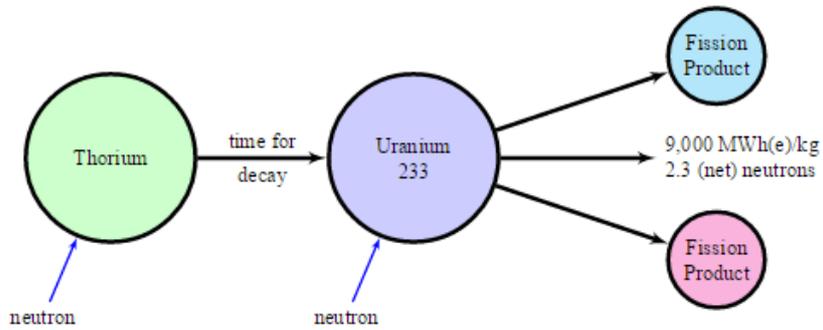
SINAP sees molten salt fuel being superior to the TRISO fuel in effectively unlimited burn-up, less waste, and lower fabricating cost, but achieving lower temperatures (600°C+) than the TRISO fuel reactors (1200°C+). Near-term goals include preparing nuclear-grade ThF<sub>4</sub> and ThO<sub>2</sub> and testing them in a MSR. The US Department of Energy is collaborating with the China Academy of Sciences on the program, which had a start-up budget of \$350 million. The target date for TMSR commercial deployment is 2032.

According to Flibe Energy, headed by nuclear scientist Kirk Sorensen, thorium is so energy dense that 6600 tonnes of it could replace the 'combined 5.3 billion tonnes of coal, 31.1 billion barrels of oil, 2.92 trillion cubic meters of natural gas, and 65,000 tonnes of uranium that the world consumes annually'. It is approximately 3X more abundant in the Earth's crust than uranium, and significant quantities have already been extracted as the by-products of existing mining operations. Most compellingly, the energy output of a LFTR, per metric ton of thorium ore, is estimated to be 200X greater than the output of a Light Water Reactor (a type of PWR).

[Flibe Energy is a startup that is also trying to develop Liquid Fluoride Thorium Reactors.](#)

Flibe Energy in the USA is studying a 40 MW two-fluid graphite-moderated thermal reactor concept based on the 1970s MSRE. It uses lithium fluoride/beryllium fluoride (FLiBe) salt as its primary coolant in both circuits. This is based on earlier US work on the molten salt reactor program. Fuel is uranium-233 bred from thorium in FLiBe blanket salt. Fuel salt circulates through graphite logs. Secondary loop coolant salt is sodium-beryllium fluoride (BeF<sub>2</sub>-NaF). A 2 MWt pilot plant is envisaged, and eventually 2225 MWt commercial plants.





SOURCES – Adam smith, Flibe Energy, World Nuclear Association, youtube

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