Wireless receiver blocks interference for better mobile device performance

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The growing prevalence of high-speed wireless communication devices, from 5G mobile phones to sensors for autonomous vehicles, is leading to increasingly crowded airwaves. This makes the ability to block interfering signals that can hamper device performance an even more important—and more challenging—problem.

With these and other emerging applications in mind, MIT researchers demonstrated a new millimeter-wave multiple-input-multiple-output (MIMO) wireless receiver architecture that can handle stronger spatial interference than previous designs. MIMO systems have multiple antennas, enabling them to transmit and receive signals from different directions. Their wireless receiver senses and blocks spatial interference at the earliest opportunity, before unwanted signals have been amplified, which improves performance.

Key to this MIMO receiver architecture is a special circuit that can target and cancel out unwanted signals, known as a nonreciprocal phase shifter. By making a novel phase shifter structure that is reconfigurable, low-power, and compact, the researchers show how it can be used to cancel out interference earlier in the receiver chain.

Their receiver can block up to four times more interference than some similar devices. In addition, the interference-blocking components can be switched on and off as needed to conserve energy.

In a mobile phone, such a receiver could help mitigate signal quality issues that can lead to slow and choppy Zoom calling or video streaming.

"There is already a lot of utilization happening in the frequency ranges we are trying to use for new 5G and 6G systems. So, anything new we are trying to add should already have these interference-mitigation systems installed. Here, we've shown that using a nonreciprocal phase shifter in this new architecture gives us better performance.

"This is quite significant, especially since we are using the same integrated platform as everyone else," says Negar Reiskarimian, the X-

Window Consortium Career Development Assistant Professor in the Department of Electrical Engineering and Computer Science (EECS), a member of the Microsystems Technology Laboratories and Research Laboratory of Electronics (RLE), and the senior author of a paper on this receiver.

Reiskarimian wrote the paper with EECS graduate students Shahabeddin Mohin, who is the lead author, Soroush Araei, and Mohammad Barzgari, an RLE postdoc. The work was recently presented at the IEEE Radio Frequency Circuits Symposium and received the Best Student Paper Award.

Blocking interference

Digital MIMO systems have an analog and a digital portion. The analog portion uses antennas to receive signals, which are amplified, down-converted, and passed through an analog-to-digital converter before being processed in the digital domain of the device. In this case, digital beamforming is required to retrieve the desired signal.

But if a strong, interfering signal coming from a different direction hits the receiver at the same time as a desired signal, it can saturate the amplifier so the desired signal is drowned out. Digital MIMOs can filter out unwanted signals, but this filtering occurs later in the receiver chain. If the interference is amplified along with the desired signal, it is more difficult to filter out later.

"The output of the initial low-noise amplifier is the first place you can do this filtering with minimal penalty, so that is exactly what we are doing with our approach," Reiskarimian says.

The researchers built and installed four nonreciprocal phase shifters immediately at the output of the first amplifier in each receiver chain, all connected to the same node. These phase shifters can pass signal in both directions and sense the angle of an incoming interfering signal. The devices can adjust their phase until they cancel out the interference.

The phase of these devices can be precisely tuned, so they can sense and cancel an unwanted signal before it passes to the rest of the receiver, blocking interference before it affects any other parts of the receiver. In addition, the phase shifters can follow signals to continue blocking interference if it changes location.

"If you start getting disconnected or your signal quality goes down, you can turn this on and mitigate that interference on the fly. Because ours is a parallel approach, you can turn it on and off with minimal effect on the performance of the receiver itself," Reiskarimian adds.

A compact device

In addition to making their novel phase shifter architecture tunable, the researchers designed them to use less space on the chip and consume less power than typical nonreciprocal phase shifters.

Once the researchers had done the analysis to show their idea would work, their biggest challenge was translating the theory into a circuit that achieved their performance goals. At the same time, the receiver had to meet strict size restrictions and a tight power budget, or it wouldn't be useful in real-world devices.

In the end, the team demonstrated a compact MIMO architecture on a 3.2-square-millimeter chip that could block signals which were up to four times stronger than what other devices could handle. Simpler than typical designs, their phase shifter architecture is also more energy efficient.

Moving forward, the researchers want to scale up their device to larger systems, as well as enable it to perform in the new frequency ranges utilized by 6G wireless devices. These frequency ranges are prone to powerful interference from satellites. In addition, they would like to adapt nonreciprocal phase shifters to other applications.

More information: Mohin et al. A Blocker-Tolerant mm-Wave MIMO Receiver with Spatial Notch Filtering Using Non-Reciprocal Phase-Shifters for 5G Applications. (2024). radiuslab.mit.edu/RMo1A-4-PDF.pdf

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