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Tech Notes

Multiple-Antenna Techniques for Wireless Communications

Multiple-antenna technology is a rich area of research. Whether for future military wireless networks, soldier radios, autonomous sensors, or robotics, the demand for improved performance may be met with multiple-antenna communication links and the advanced technology making those links effective.

Lincoln Laboratory is investigating multiple-input multiple-output (MIMO) techniques to improve the robustness and performance of wireless links. Here, the term multiple-input multiple-output refers to the use of an array of antennas for both transmitting and receiving. MIMO approaches show promise of enabling better wireless communications because they mitigate problems inherent in ground-to-ground links, which are the most common links used by wireless devices, including cell phones and WiFi.

Typically, ground-to-ground links are not line of sight. The electromagnetic waves transmitted from the antennas bounce around the environment in a complicated fashion and end up at the receiver coming from multiple directions and with varying delays. The effect produced by the direction/delay interactions is referred to as multipath, a condition that must be accommodated by ground-to-ground systems. With the use of MIMO communication techniques [1], multipath need not be a hindrance and can be exploited to increase potential data rates and simultaneously improve the robustness of the links (Figure 1).

Increased military and commercial dependence on wireless communication has intensified the need for more robust links. For example, the lack of adequately robust, reliable links has limited the usefulness of remotely controlled robots in military environments. More is also being asked of the links in terms of flexibility of use and higher data rates. Furthermore, ad hoc wireless networks, which are inevitably becoming integrated into military and commercial applications, require more robust, flexible, and higher-data-rate links.

Lincoln Laboratory is pushing the limits of MIMO technology, developing record-setting space-time codes. Space-time codes describe what is transmitted by the array of transmitters in a MIMO communication link [2]. These

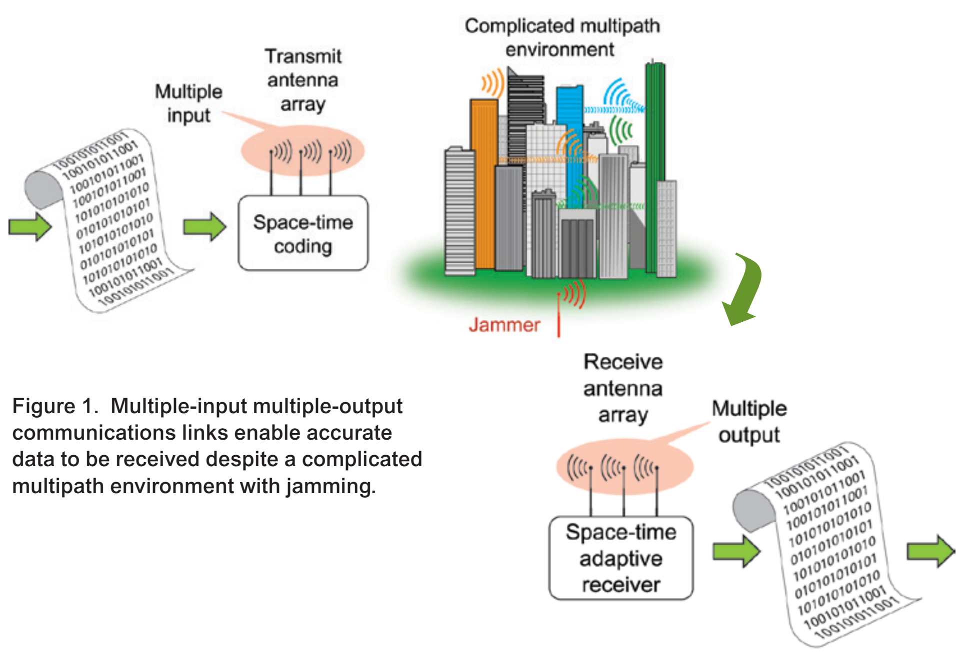

Figure 1. Multiple-input multiple-output communications links enable accurate data to be received despite a complicated multipath environment with jamming.

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codes employ advanced coding concepts along with sophisticated iterative receivers. The Laboratory-developed codes, which are allowing the largest data rates for a given transmit power, have been demonstrated theoretically and experimentally.

Advanced Receiver Techniques

The Laboratory has also developed and demonstrated advanced receiver techniques that enable communication in the presence of interference and jamming without significant degradation in link performance [3]. The diversity provided by multiple transmitting antennas allows the system to avoid signal interference, and the multiple receiving antennas allow the system to mitigate the effects of interference. Mitigation is achieved by subtracting the jamming and interference components of the signal seen at one receiving antenna from signals received at other antennas. While the idea of using multiple antennas to null or mitigate jammers is not new, the Laboratory has pushed these approaches significantly and achieved remarkable mitigation performance in a variety of applications (communications, geolocation, GPS).

With the use of MIMO communication techniques, multipath need not be a hindrance and can be exploited to increase potential data rates and simultaneously improve the robustness of wireless links.

Space-time adaptive processing (STAP) is a class of techniques used to improve mitigation performance. In this context, "space" refers to the multiple antennas and "time" refers to delay variations caused by multipath. The STAP approaches, which allow for improved matching of the signals seen at the receiving antennas, enable the subtraction to work better; therefore, jammer mitigation is improved.

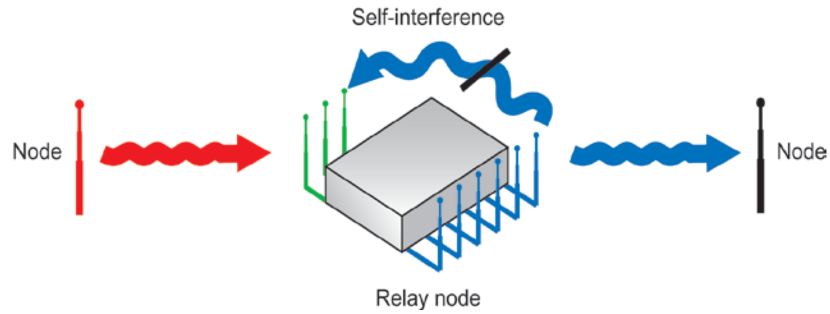

Figure 2. A full-duplex relay employing self-interference mitigation may provide the ability to build full-duplex nodes that simultaneously transmit and receive at the same frequency.

Without using multiple-antenna mitigation techniques, a typical communication link would simply fail or at best be forced to reduce its data rate by factors of thousands to millions, making the links effectively useless. Advanced mitigation techniques such as STAP make the loss in performance essentially negligible.

Joint Transmit/Receive Arrays

The Laboratory is also extending its MIMO research to include the adaptive use of joint transmitting and receiving antenna arrays. In order to do this, the transmitter must have an estimate of the channel, i.e., the environment between the transmitting antenna array and the receiving antenna array. Given this estimate of the channel, the transmitter can make intelligent decisions that improve performance of the intended link while simultaneously reducing interference to other communication links.

Extreme examples of this joint transmitter and receiver adaptation have been demonstrated theoretically and experimentally [4]. In one example, a node with separate transmitting and receiving antenna arrays optimizes the space-time coding such that the receiving antennas are protected from the transmitted energy. The residual self-interference signal power is mitigated using advanced receiver techniques such as STAP and temporal-interference mitigation (Figure 2).

By combining these techniques with a mechanical design that provides natural transmitter-to-receiver isolation, it may be possible to build full-duplex nodes that simultaneously transmit and receive at the same frequency. This approach would break one of the fundamental bottlenecks in wireless networking: nodes that operated in a half-duplex mode had to choose to either transmit or receive at a given frequency. This full-duplex-node technology makes possible various military and commercial applications, such as wireless data networks and robotics systems. ■

References

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