



In-band Full-Duplex Radios for Military Communications

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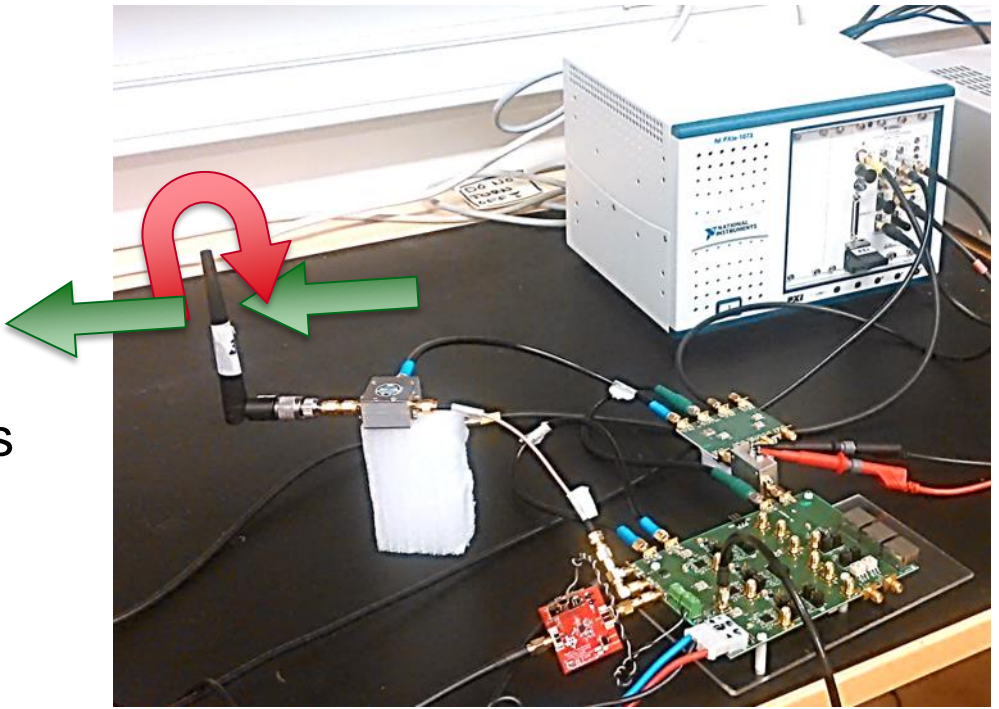
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THE RECENT ADVANCES IN NON-MILITARY SYSTEMS



In-band Full-Duplex (IBFD)

- IBFD radios are capable of simultaneously transmitting and receiving (STAR) at the same center frequency
 - self-interference (SI)
- The basic scientific work is giving way for R&D projects in the telecom industry
 - SI cancellation (SIC) at upper UHF bands
 - communication applications

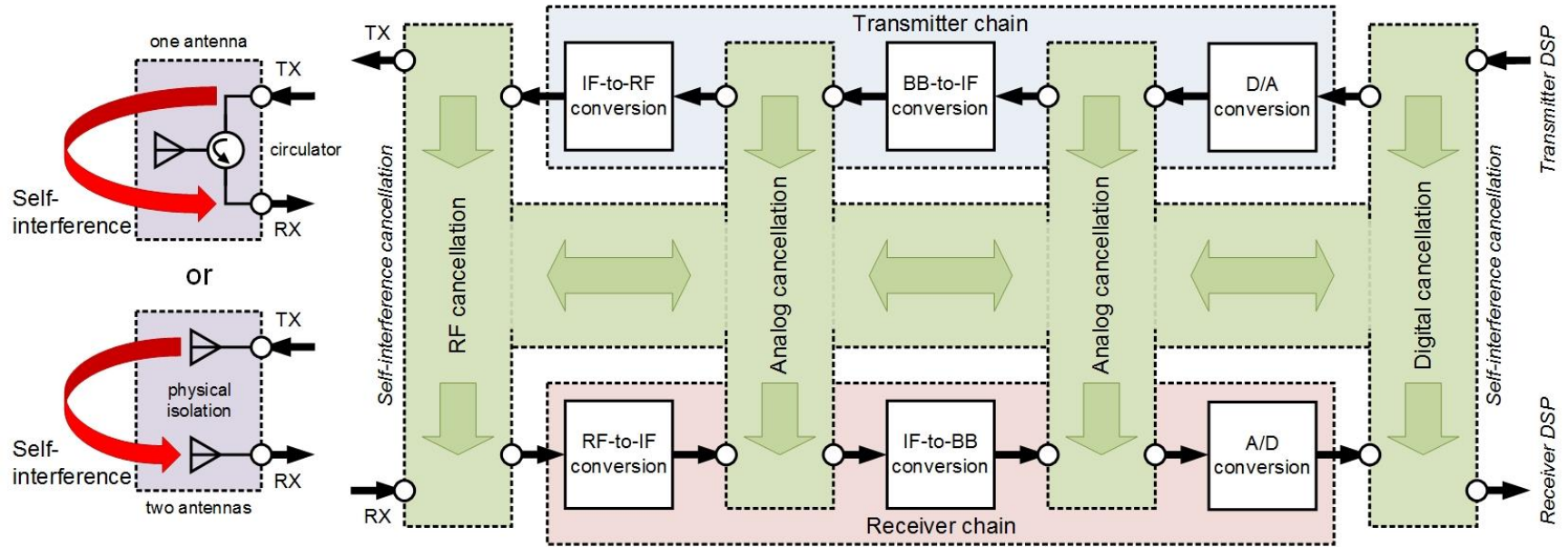




with Intel at Mobile World Congress

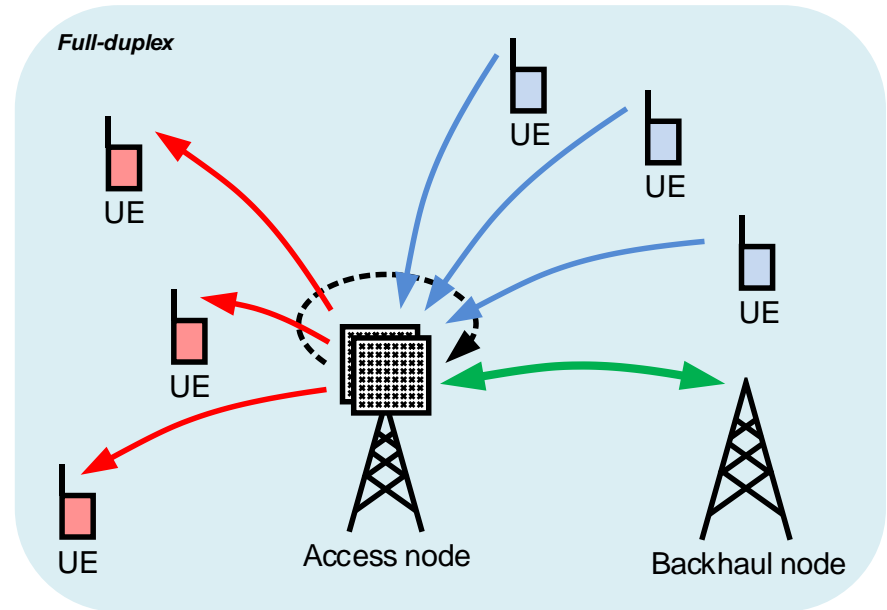
In 2015, we demonstrated that **beyond 100 dB total cancellation** can be achieved with realistic circuits and processing algorithms!

Transceiver Architectures



Communication Applications

- STAR operation facilitates up to **doubled data rate per allocated frequency band** by frequency reuse in wireless communication systems
- Military radio channels are scarce and congested too
 - The defense industry shares the telecom industry's motivation for improving spectral efficiency in tactical radio communications



THE FUTURE ADVANCES IN MILITARY SYSTEMS

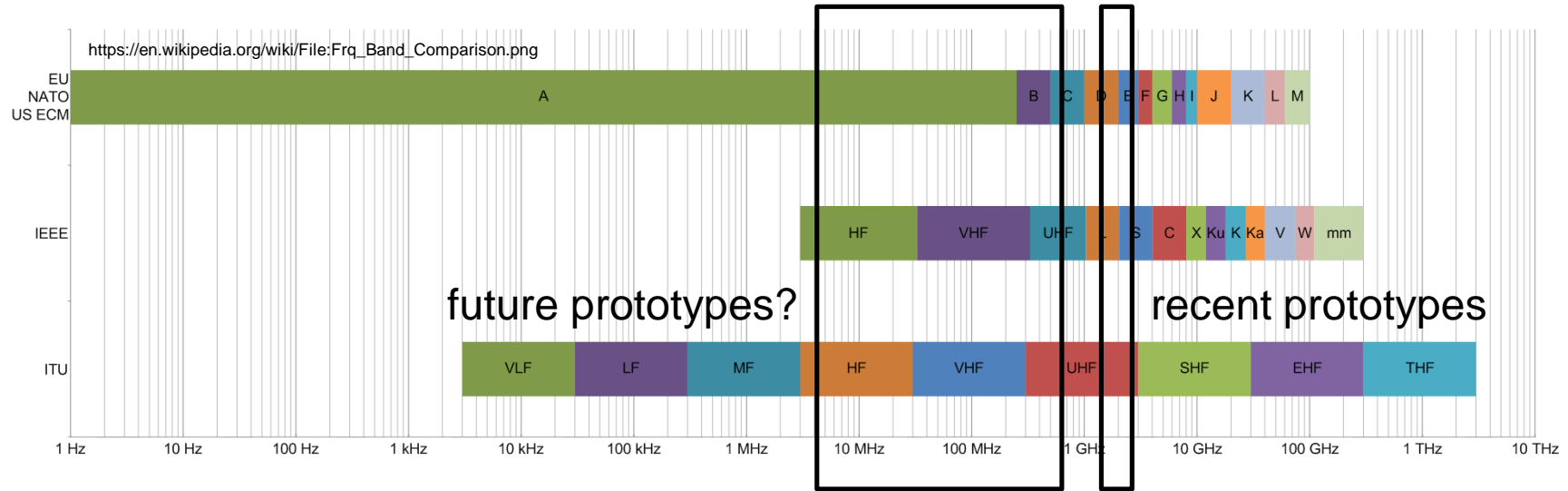


The Prior Art

- The only explicit and elaborate reference to *military* full-duplex radios in open literature has been the passage at right
 - from page 120 in S. Hong, J. Brand, J. I. Choi, M. Jain, J. Mehlman, S. Katti, and P. Levis, “Applications of self-interference cancellation in 5G and beyond,” *IEEE Communications Magazine*, vol. 52, no. 2, Feb. 2014.

By virtue of its fundamental nature, SIC is likely to have an impact far beyond 5G. Every future radio, from WiFi [4] to military grade jammers [9], can benefit from this technology. In WiFi, for example, it allows an access point (AP) to eliminate co-channel broadband noise, enabling it to simultaneously utilize multiple independent channels, multiplying the effective capacity of an AP even without modification of the clients. In military applications, jammers flood the airwaves with strong transmission to prevent other devices from communicating (e.g., cell phones to activate improvised explosive devices). But as it does so, it also prevents its own radios from transmitting, making communication impossible. With SIC technology, the military could continue to disrupt enemy communications and at the same time listen to its own troop communications, thus saving lives in the field.

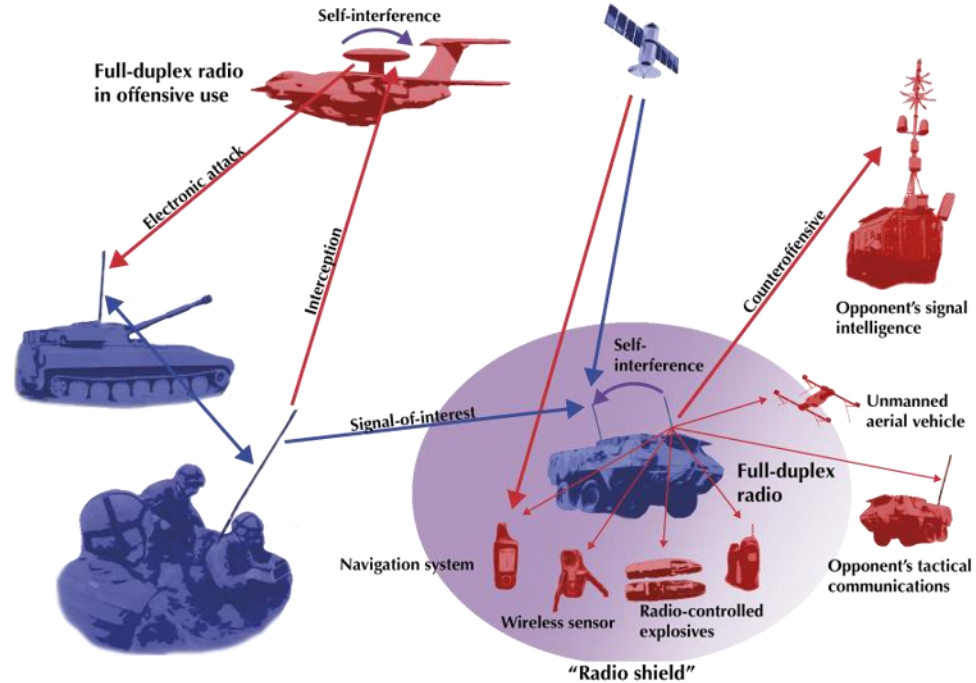
SIC at Military Radio Bands



- Implementing the STAR capability for military radio systems is still largely an open research problem

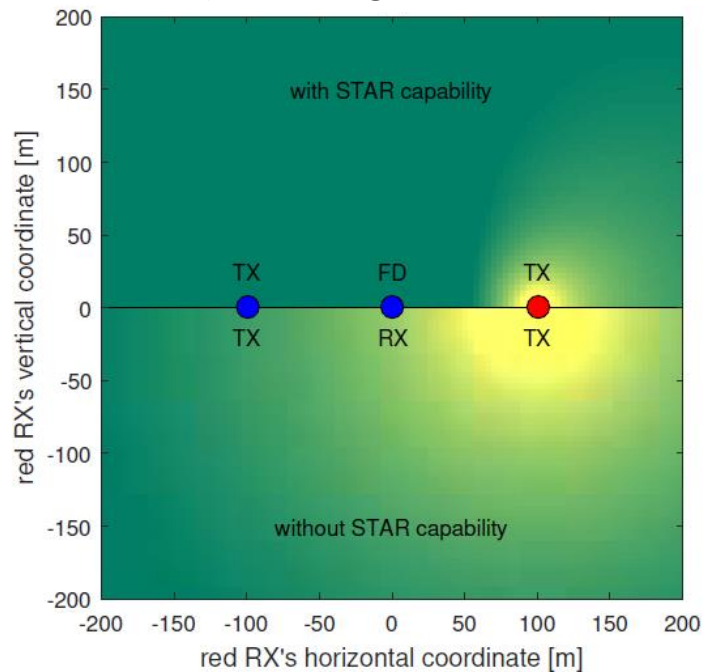
Novel Military Applications

- Spectrally efficient two-way tactical communications
- Tactical communications with electronic warfare (EW)
 - information reception with simultaneous electronic attack
 - signals intelligence during information transmission
 - signals intelligence with simultaneous electronic attack

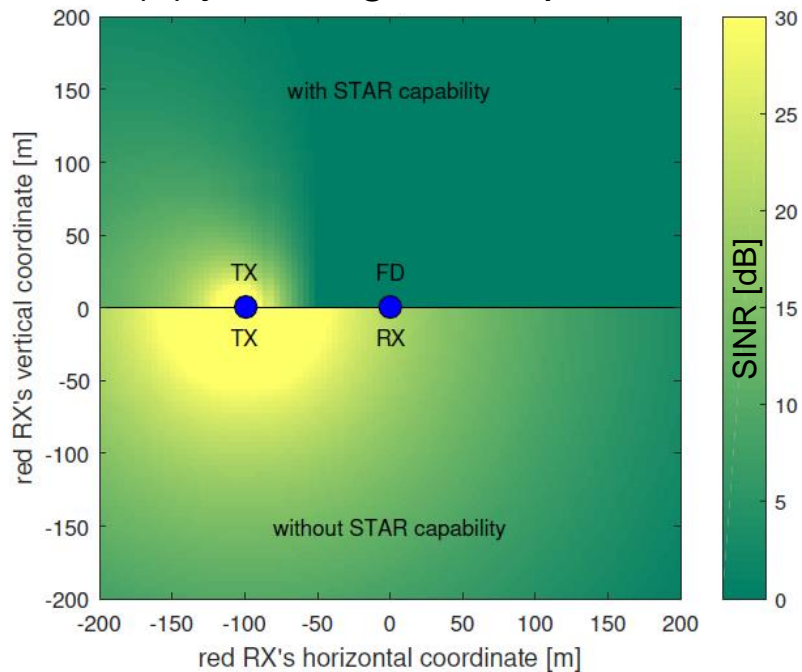


Examples of IBFD in EW

(a) jamming UAV or IED



(b) jamming interception



Conclusion

- The past research has already generated thorough understanding on the prospects and challenges in *civilian/commercial* applications
 - our research characterizes all and the best applications for the IBFD technology in *military* radio communication systems
 - the STAR capability is a disruptive innovation that will be adopted in some forms also at cyber-electromagnetic battles sooner or later
- A paradigm shift in tactical communications and electronic warfare?
 - armed forces could even gain a major advantage over opponents that do not possess the IBFD technology
 - new procedures and tactics to counteract the STAR capability

Acknowledgment



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References

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- [2] Z. Zhang *et al.*, “Full-duplex wireless communications: Challenges, solutions and future research directions,” *Proceedings of the IEEE*, vol. 104, no. 7, pp. 1369–1409, Jul. 2016.
- [3] T. Riihonen *et al.*, “On the prospects of full-duplex military radios,” in *Proc. International Conference on Military Communications and Information Systems*, Oulu, Finland, May 2017.
- [4] T. Riihonen *et al.*, “Inband full-duplex radio transceivers: A paradigm shift in tactical communications and electronic warfare?,” *IEEE Communications Magazine*, vol. 55, no. 10, pp. 30–36, Oct. 2017.