A wideband generalization of the near-field region for extremely large phased-arrays

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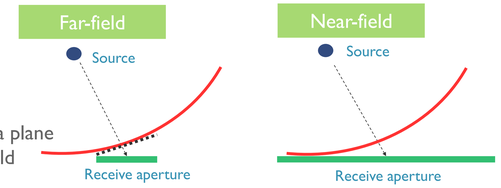
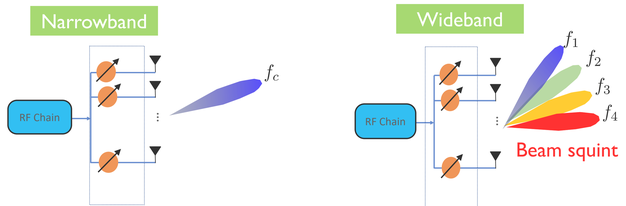
I. The transition to near-field and wideband communication

The transition from far-field to near-field



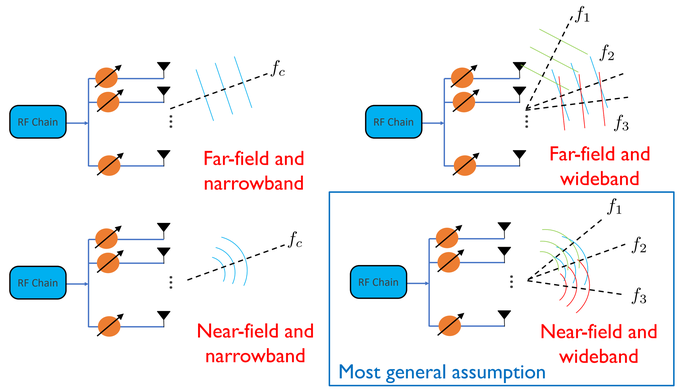
With increase in aperture, the planar wavefront approximation does not hold

The transition from narrowband to wideband



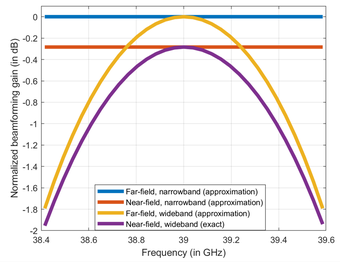
Beam shifts direction due to the mismatch between array response and beamforming phase shift

II. Joint near-field and wideband characterization

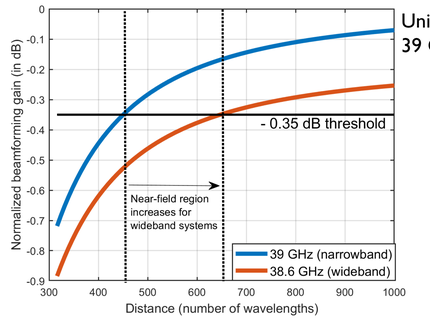


Uniform linear array with 128 antennas operating at 39 GHz, inter-antenna spacing is half-wavelength

The far-field and narrowband model overestimates the beamforming gain in a wideband and near-field scenario



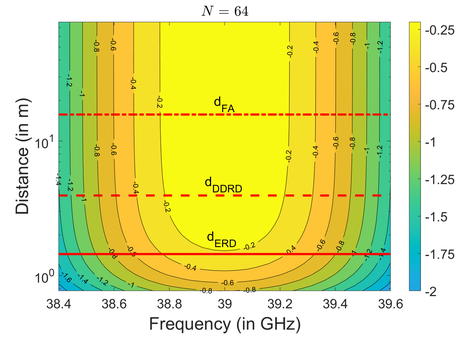
III. Bandwidth aware near-field distance (BAND)



Uniform linear array with 64 antennas operating at 39 GHz, inter-antenna spacing is half-wavelength

Bandwidth aware near-field distance (BAND) is the smallest distance beyond which the beamforming gain is always above a certain threshold [2]

Near-field region increases for wideband systems



BAND is a generalization of the conventional narrowband metrics

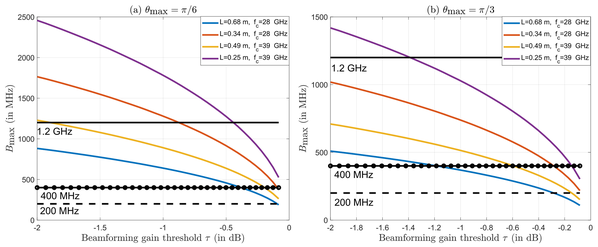
Fraunhofer distance [1]

Direction-dependent Rayleigh distance

Effective Rayleigh distance

IV. Aperture bandwidth product (ABP)

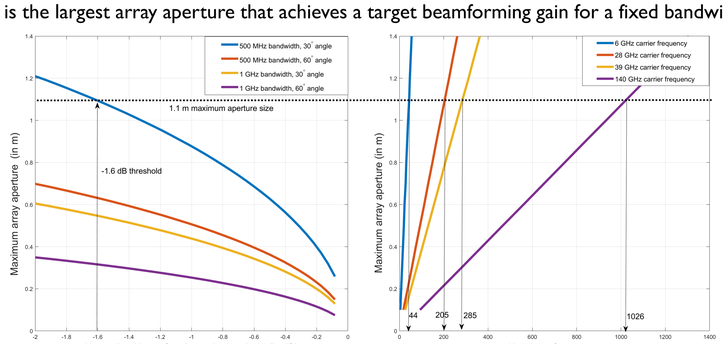
Maximum bandwidth



For a fixed carrier frequency, the maximum permissible bandwidth doubles as the aperture is halved

Maximum array aperture

What is the largest array aperture that achieves a target beamforming gain for a fixed bandwidth?



V. Key takeaways

The BAND corresponding to a particular threshold attains minima at the center frequency and increases for frequencies away from the center frequency

The proposed upper bound on the ABP is beneficial for characterizing the performance of the existing frequency-flat beamforming when scaling up in carrier frequency, bandwidth, and array aperture

VI. Future directions

The BAND definition can be extended to MIMO systems incorporating practical aspects like mutual coupling between antenna elements and polarization mismatch

The ABP can be studied for other array architectures like holographic metasurface antenna array and true time delay beamforming arrays

References

[1] E. Bjornson, O.T. Demir, and L. Sanguinetti, "A primer on near-field beamforming for arrays and reconfigurable intelligent surfaces," in Proc. 55th Asilomar Conf. Signals, Syst., Comput., 2021, pp. 105–112.
[2] N. Deshpande, M. R. Castellanos, S. R. Khosravirad, J. Du, H. Viswanathan, and R.W. Heath, "A wideband generalization of the near-field region for extremely large phased-arrays," *IEEE Wireless Commun. Lett.*, 2022.

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