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# Photonic Approaches to Increase mmWave Capacity

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# Methods for increasing data capacity

$$\text{Capacity} = M \cdot B \cdot \underbrace{\log_2 \left( 1 + \frac{S}{N} \right)}_{\text{Spectral efficiency (Shannon's capacity theorem)}}$$

Multiple channels

Bandwidth

Spectral efficiency  
(Shannon's capacity theorem)

## 1. Increase bandwidth (move to higher frequencies):

- Can lead to challenges with atmospheric losses

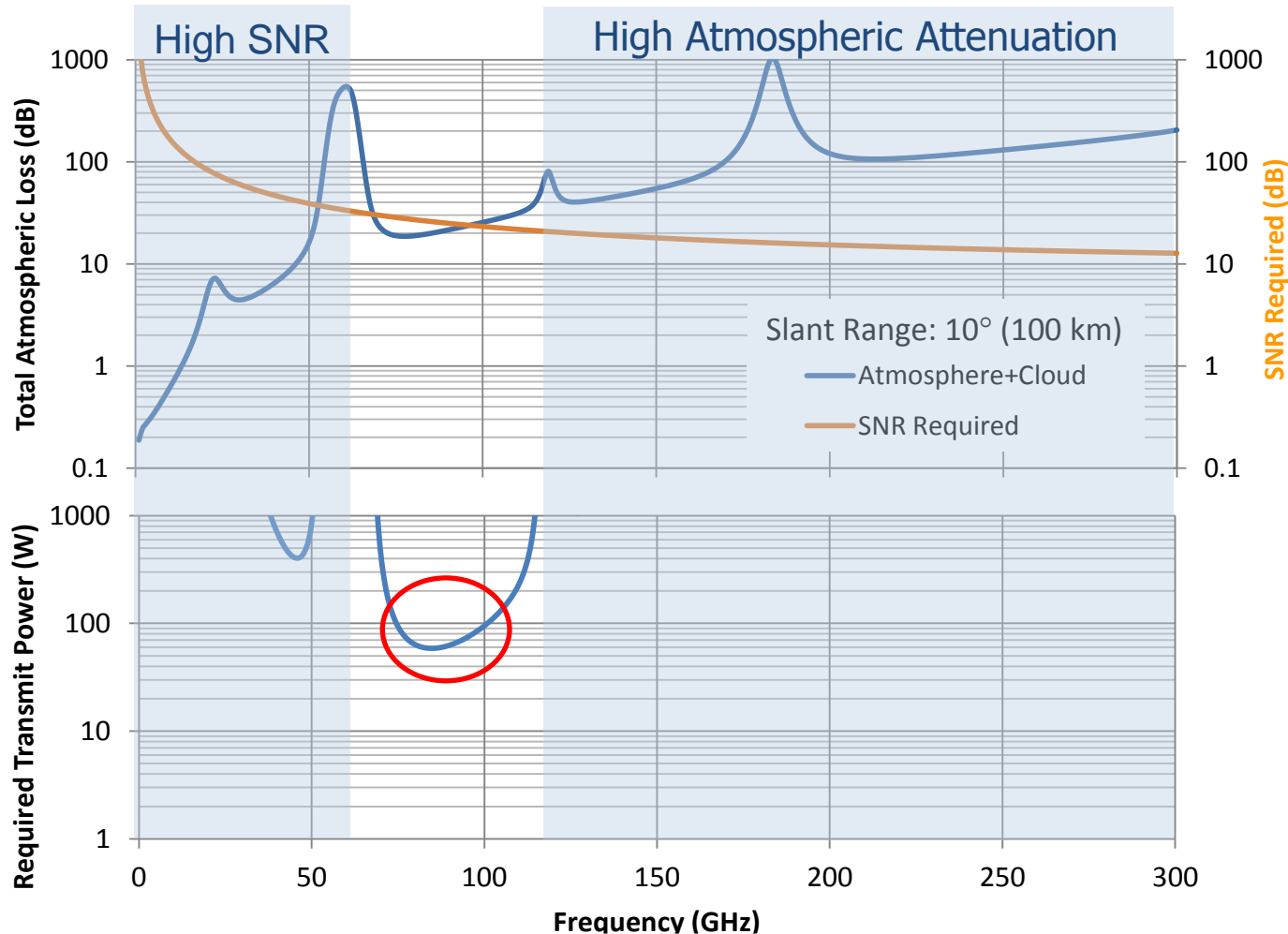
## 2. Apply spectrally efficient modulation (such as Quadrature Amplitude Modulation):

- Requires a high signal-to-noise ratio (SNR) and thus a high transmit power and/or antenna gain

## 3. Use multiple independent channels (using spatial multiplexing):

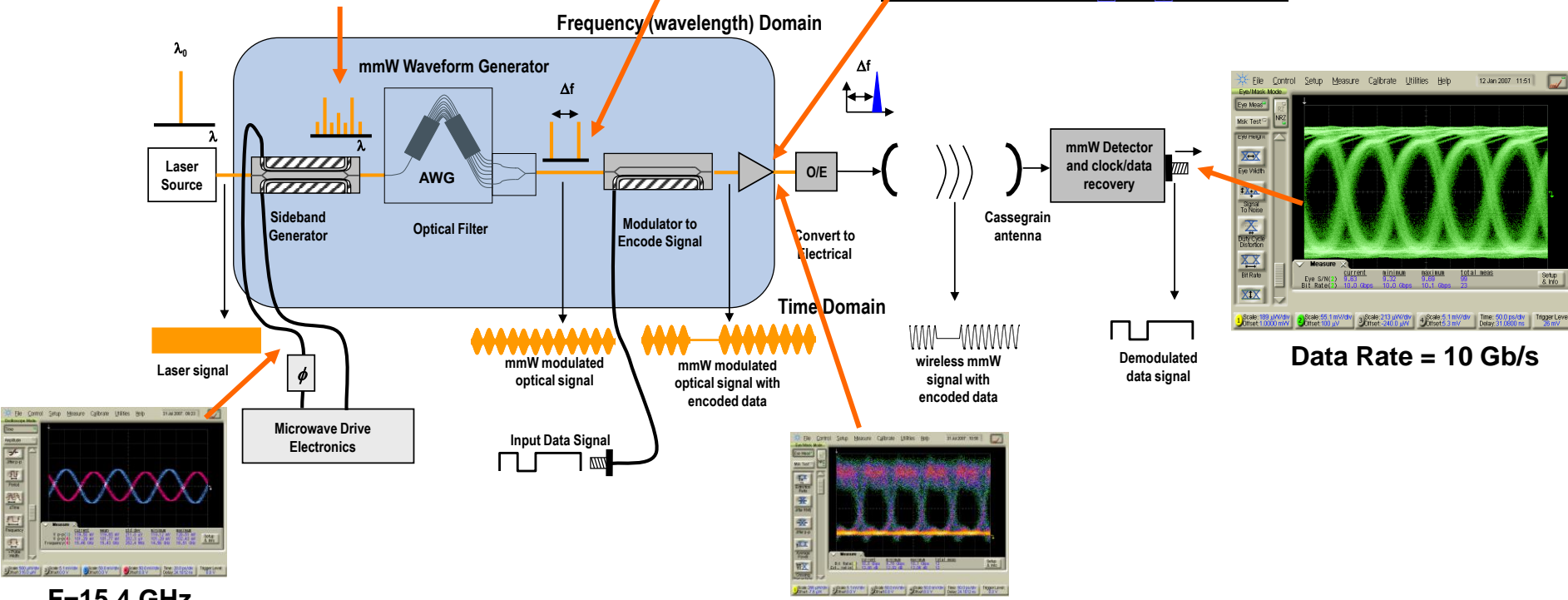
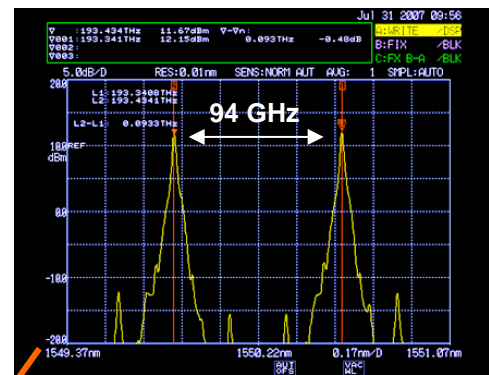
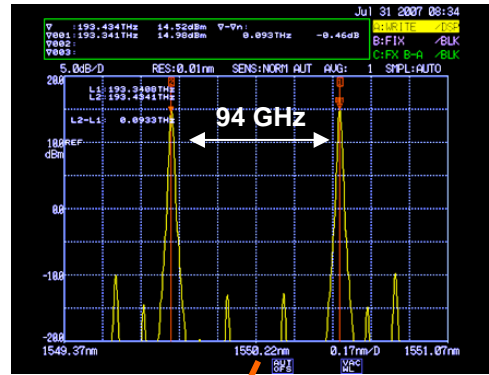
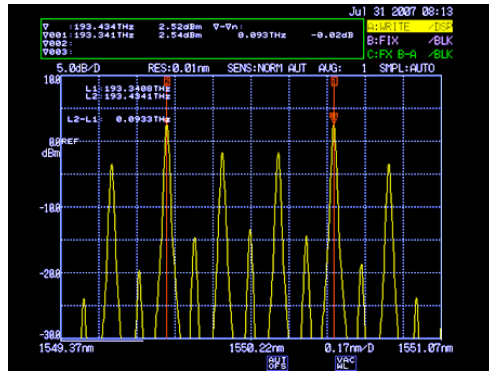
- Requires multiple apertures

# Increasing bandwidth and signal-to-noise



The spectral "sweet spot" for attaining 100 Gb/s within practical physical constraints lies between 70 and 120 GHz

# Photonic Generation of Millimeter-waves



Battelle uses photonic components to generate and modulate the millimeter-wave signals.