CYBER SECURITY FOR NEXT GENERATION LEO SATELLITES

Using Phased Array Antenna

In sub-THz frequencies

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What's New?

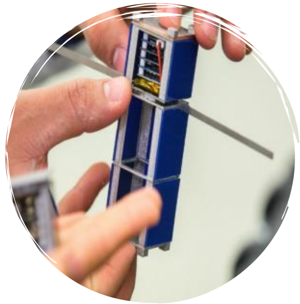
Demand

High-Capacity
Worldwide Internet

Solution

LEO Satellite
Constellation

It Means

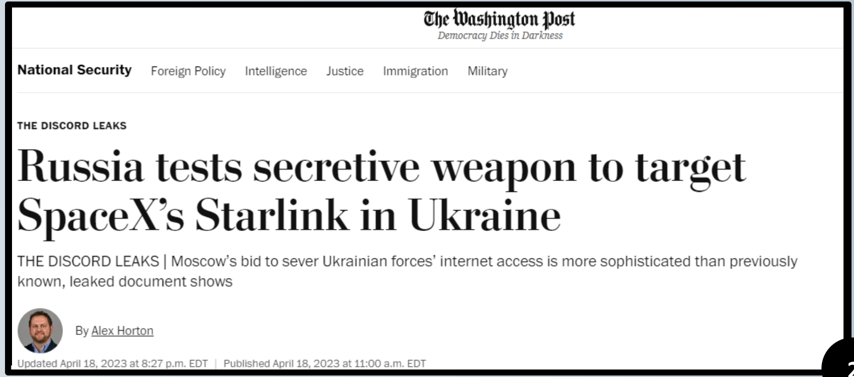


Many Small Satellites

It Allows

High Data Rates

Everywhere, Any time



The Washington Post
Democracy Dies in Darkness

National Security Foreign Policy Intelligence Justice Immigration Military

THE DISCORD LEAKS

Russia tests secretive weapon to target SpaceX's Starlink in Ukraine

THE DISCORD LEAKS | Moscow's bid to sever Ukrainian forces' internet access is more sophisticated than previously known, leaked document shows

By Alex Horton

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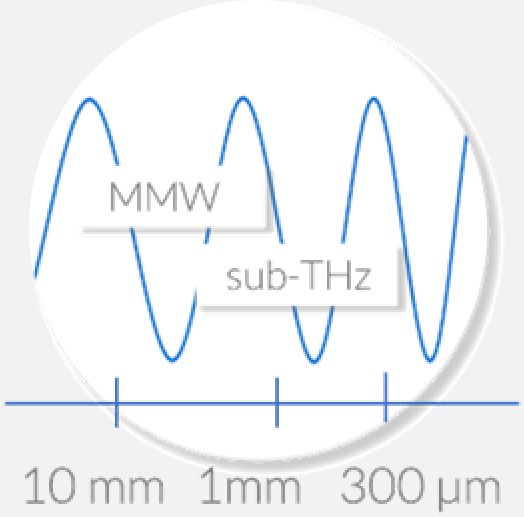
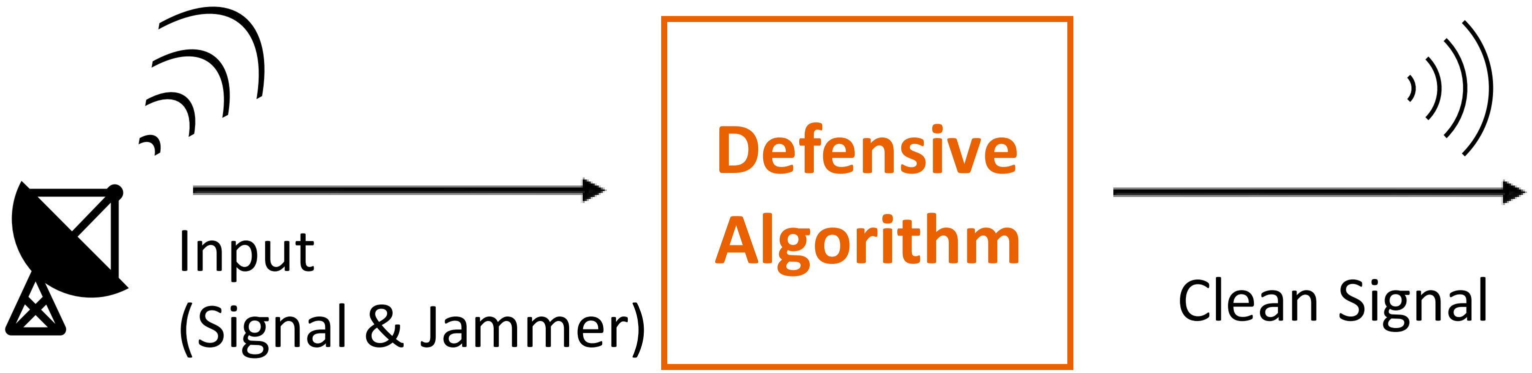
Our Idea

$$\lambda = \frac{c}{f}$$

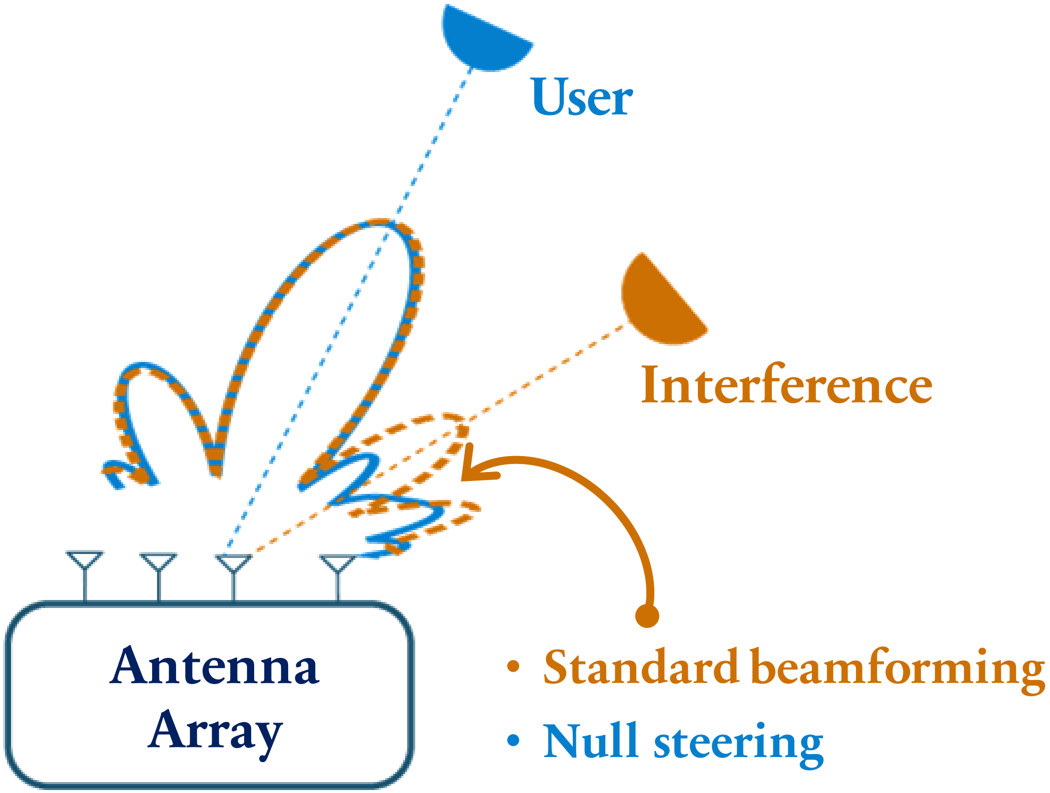


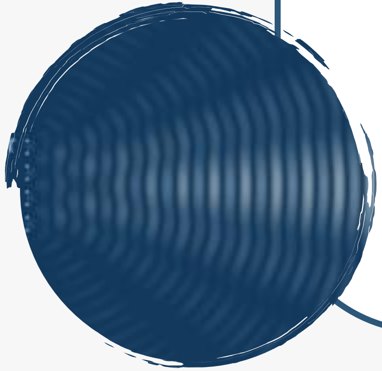
Sub-THz band
Inter-Satellite Links

Our Goal



Our Vision: Phased Array sub-THz Inter-Satellite Links



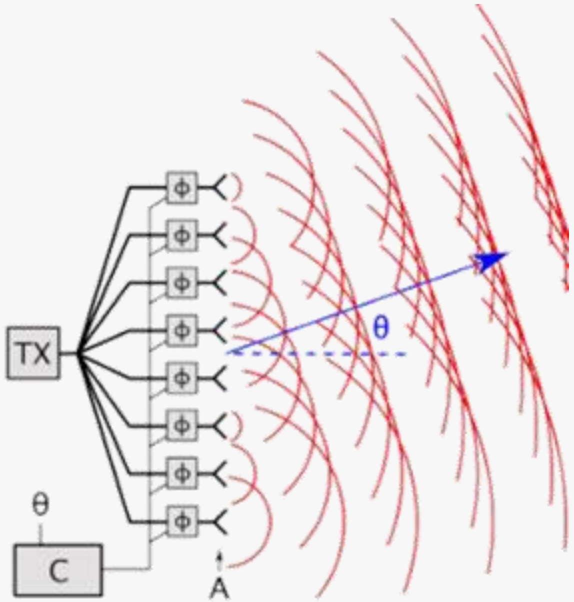


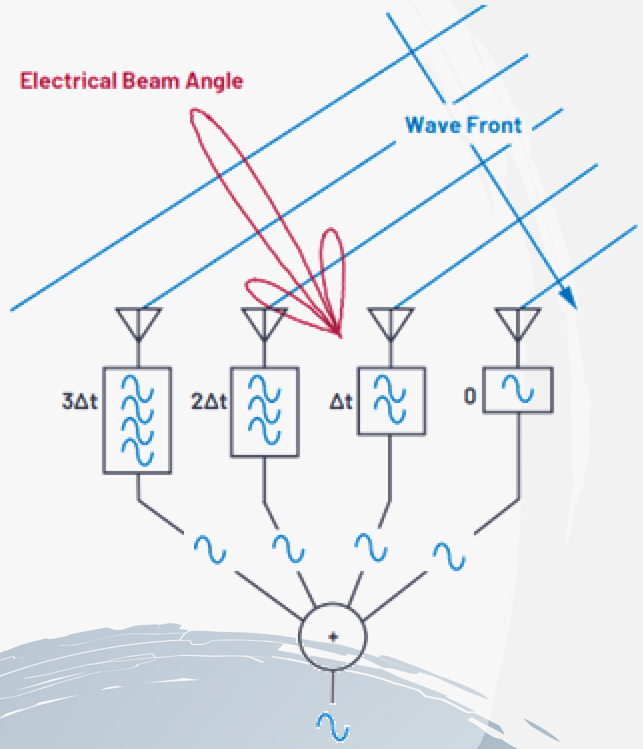
Sub-THz Transmission

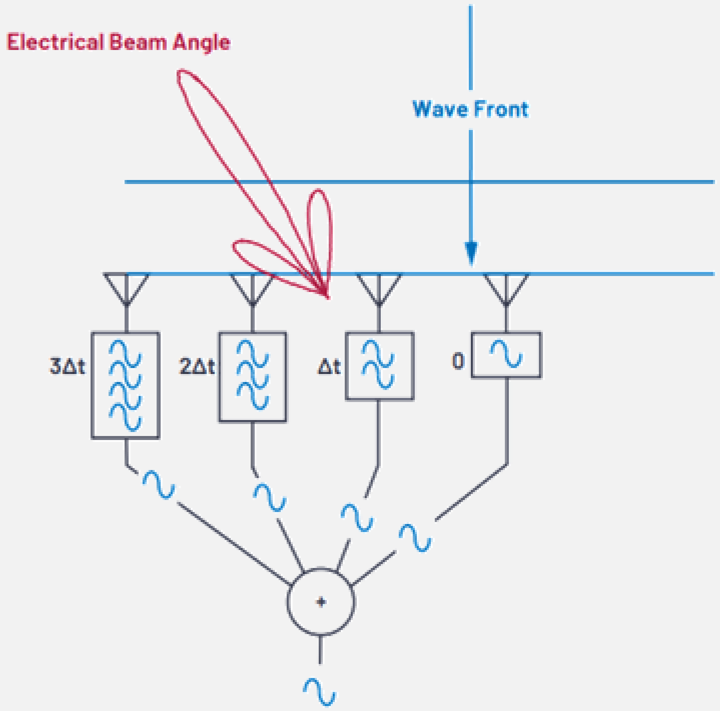
Defense System (Nulling)

Electrically Steerable

Phased Array Physics







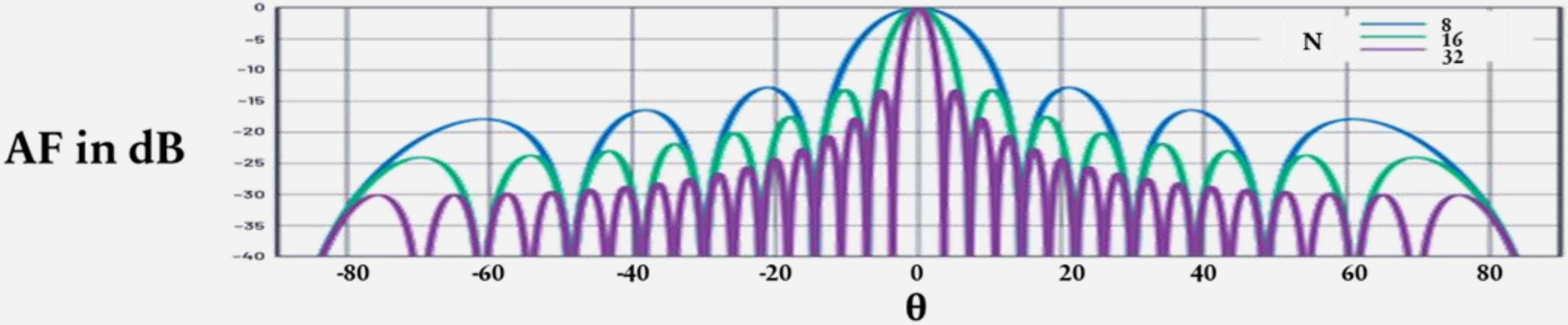
Elements phase shift:

$$\Delta\boldsymbol{\Phi} = \boldsymbol{d} \cdot \mathbf{sin}(\boldsymbol{\theta_0})$$

$\boldsymbol{d} = \frac{\lambda}{2}$: Distance between the elements

$\boldsymbol{\theta_0}$: Desired angle

Array Factor



The array factor can be thought of as the Antenna's **Gain Filter** and is calculated based on:

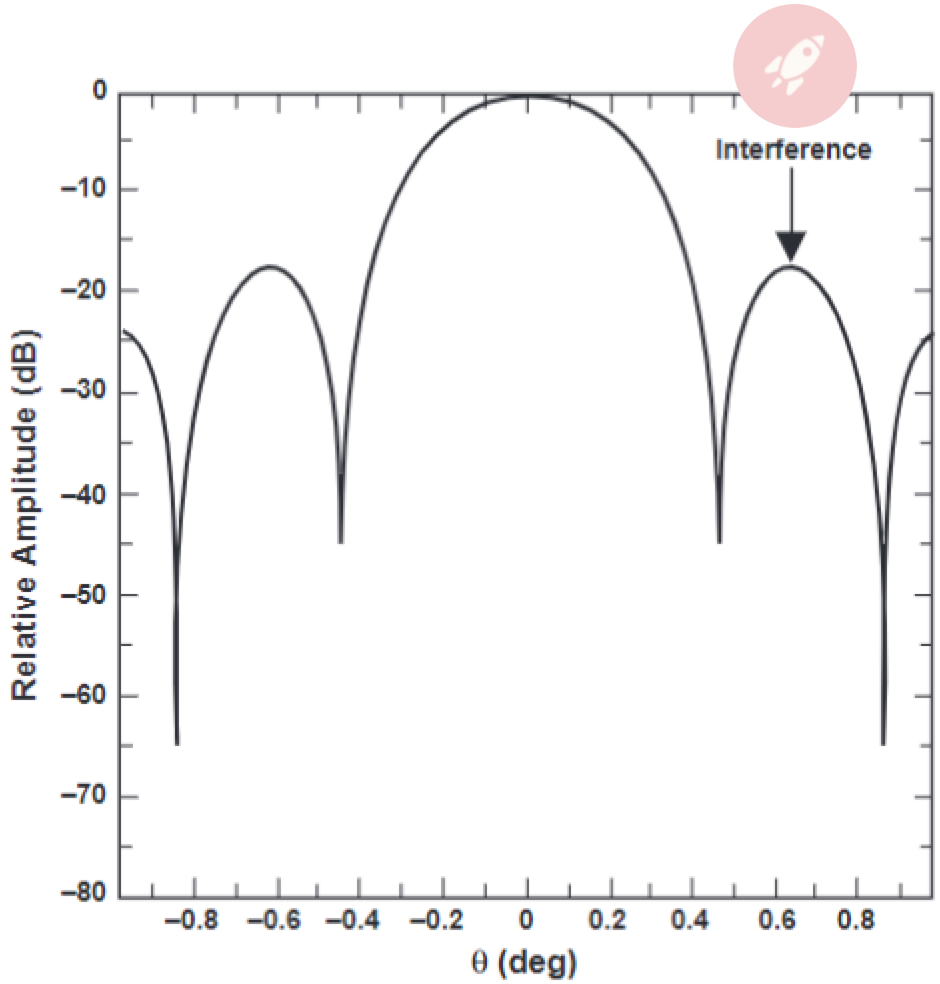
- array geometry (distance between elements)
- beam weights (amplitude and phase).

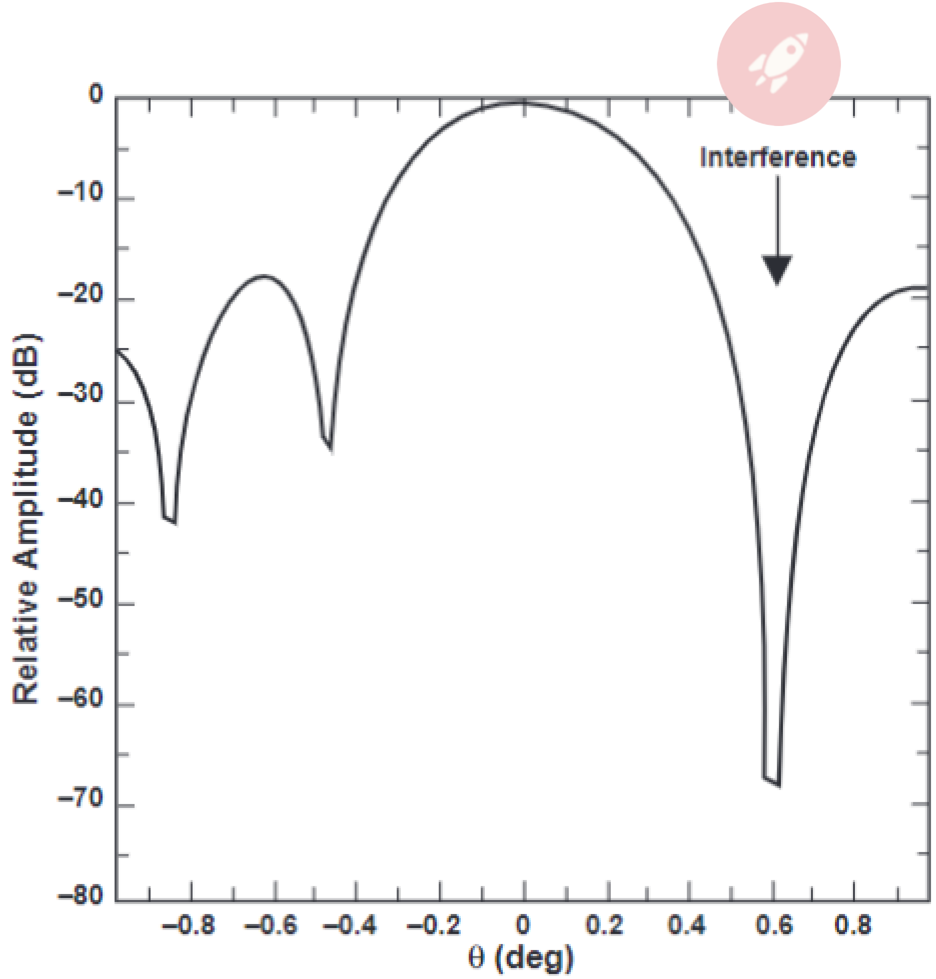
$$AF[\theta, \Delta\Phi] = \frac{sin\left(N\left[\frac{\pi d}{\lambda}sin(\theta) - \frac{\Delta\Phi}{2}\right]\right)}{Nsin\left(\frac{\pi d}{\lambda}sin(\theta) - \frac{\Delta\Phi}{2}\right)}$$

θ - Direction for AF measurement.

$\Delta\Phi$ - Phase Shift per element.

Adaptive Nulling

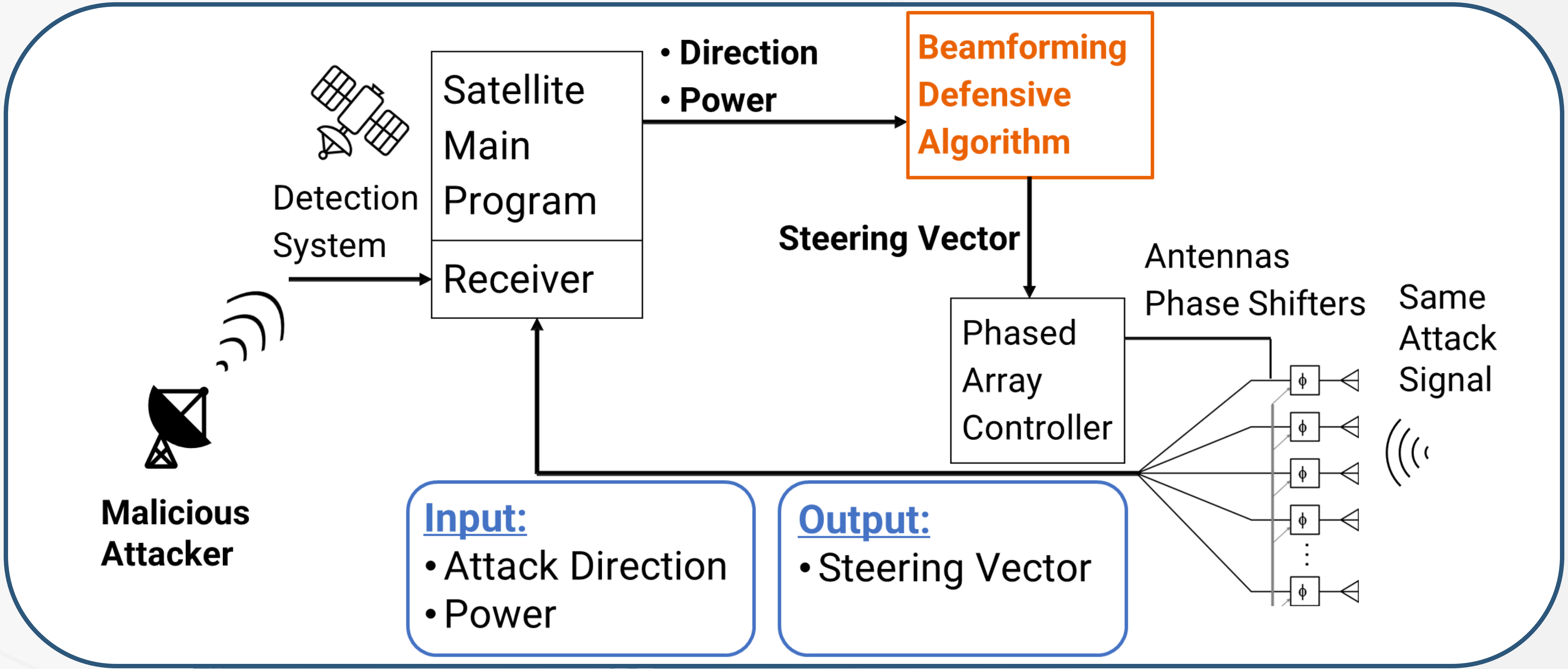




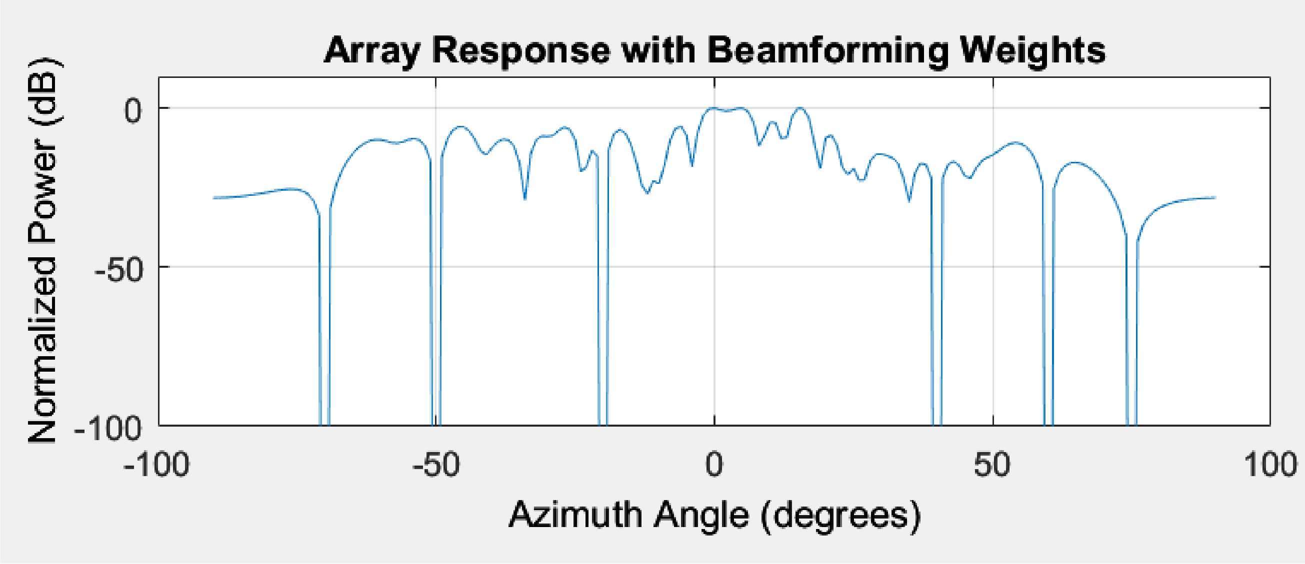
Our Solution

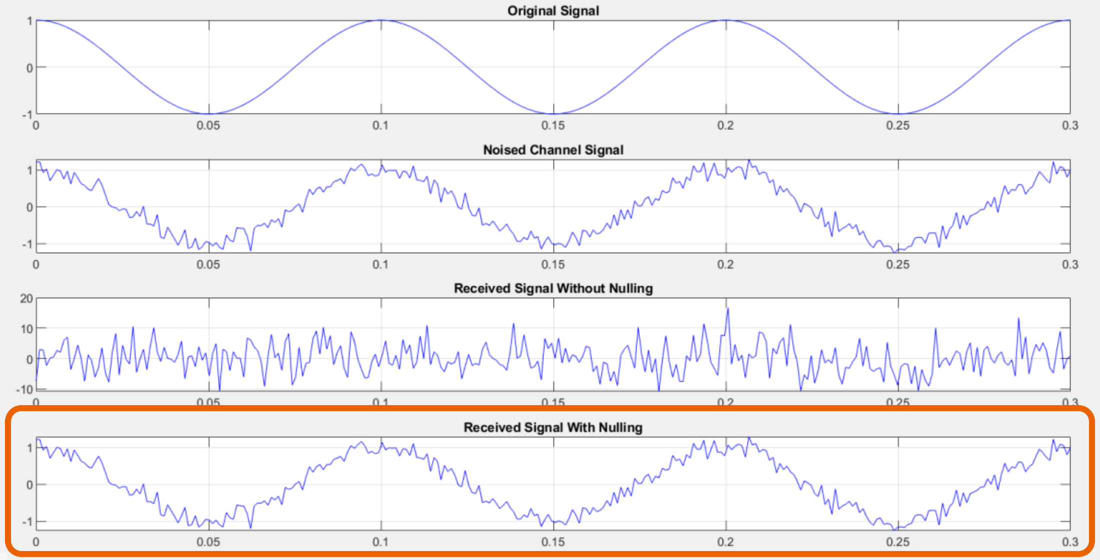
We propose a **software add-on** to derive the antenna's steering-vector in real-time.

Since the antenna operates in the **sub-THz** band, we must maintain **high direction accuracy**.



Simulation





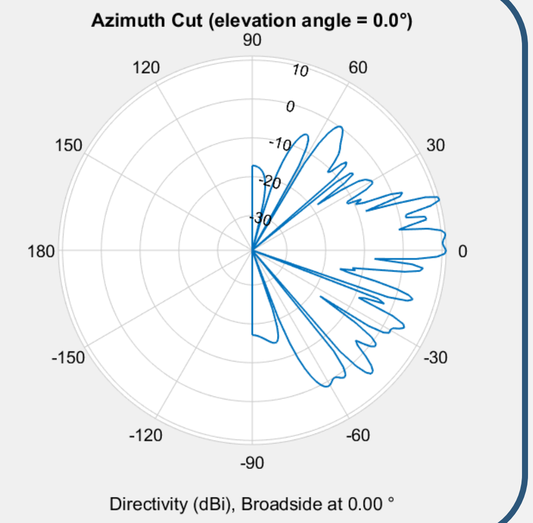
<u>Antenna:</u> Uniform Linear Phased Array with 30 antennas

<u>Friendly Signals:</u> Arriving from [0°,5°,15°]

<u>Attacker Signal:</u> Arriving from [-70°,-50°,-20°, 40°, 60°,75°]

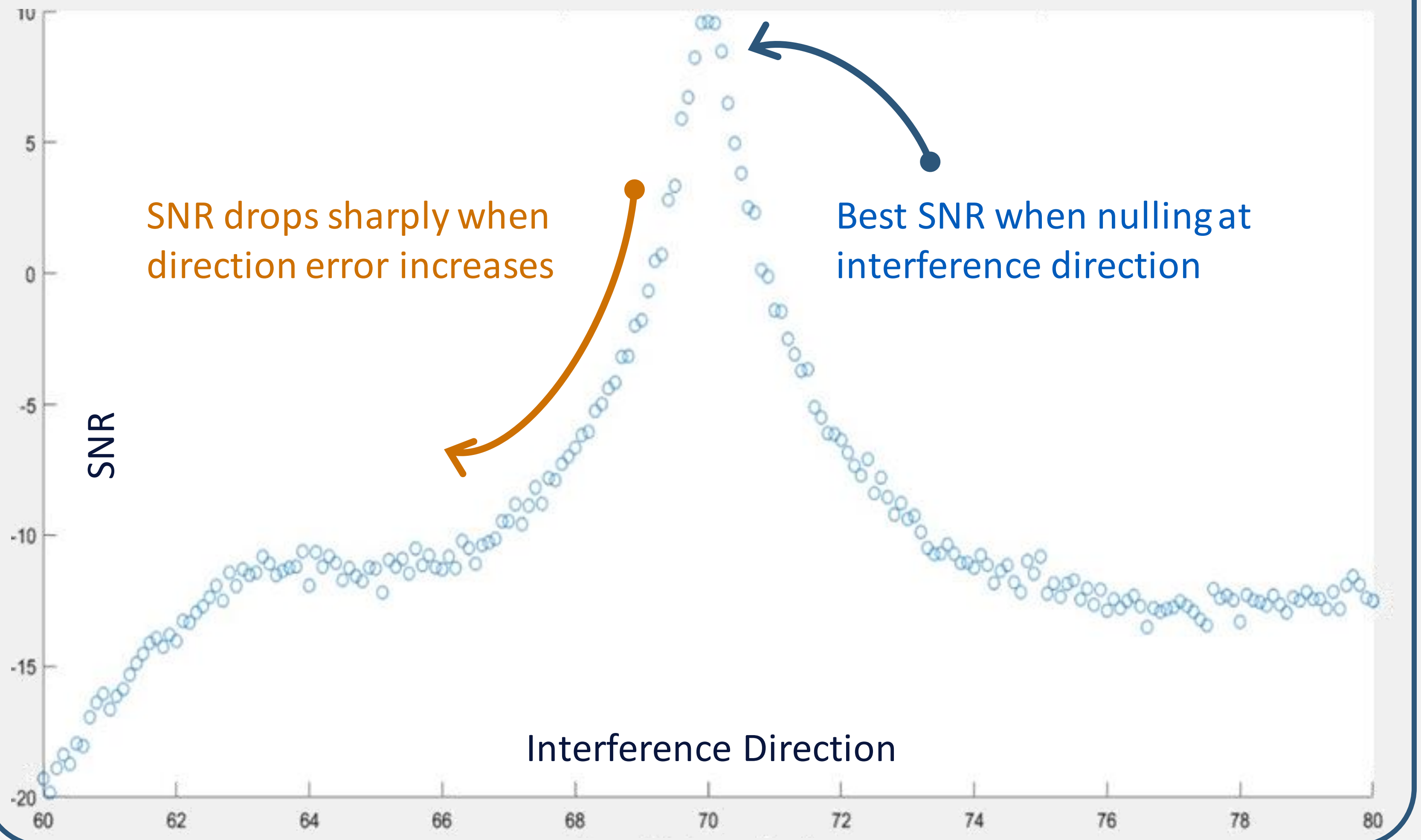
$$\Delta SNR_{With\ Nulling} = SNR_{With\ Nulling} - SNR_{Noised\ Channel} = 0\ dB$$

$$\Delta SNR_{Without\ Nulling} = SNR_{Without\ Nulling} - SNR_{Noised\ Channel} = -26.62\ dB$$



Decrease in SNR vs Direction Error Increase

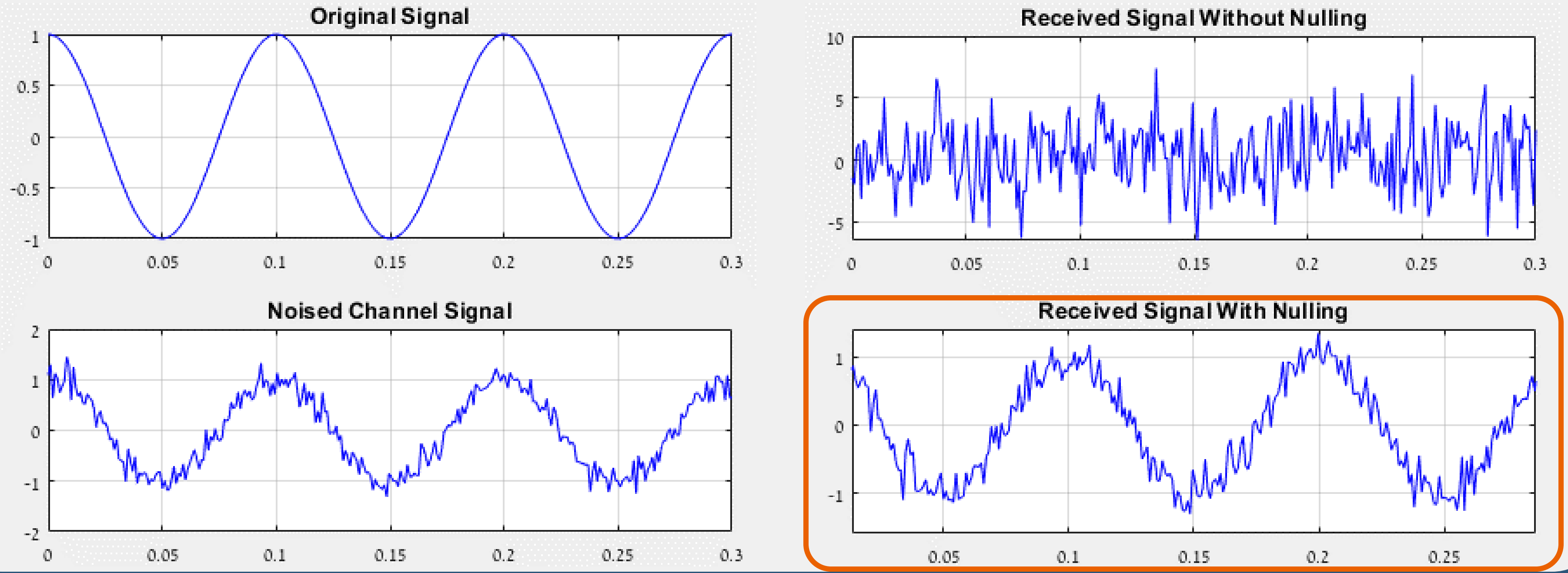
SNR as function of interference direction, with fixed nulling at $70°$

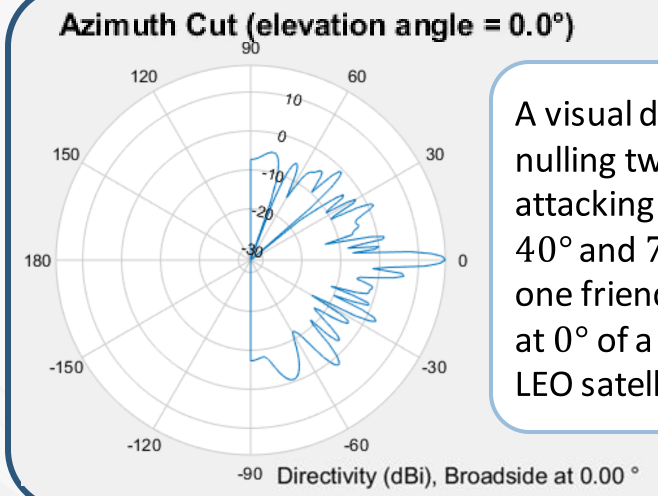


SNR decreases very fast with any directional error. This implies a **strong precision demand** of the used hardware.

We can see that any error larger than 1° will already cause SNR=0.

Results With Nulling Error of $0.1°$





A visual display of nulling two attacking signals at $40°$ and $70°$, with one friendly beam at $0°$ of a defended LEO satellite.

Our findings show a much-improved SNR when nulling with our method, even in extreme situations.

In this situation there are two jam signals at $40°$ and $70°$.

We consider an **error at the nulling direction of $0.1°$,** and **still get a readable signal**, with $\Delta SNR = -0.998$ (79.6%).

Obstacles & Solutions

Obstacles

Signal Directivity & Power	Assuming Input
Several Attackers	Scalable Algorithm (to N-1 attackers)
No Real-World Simulation	Rely on MATLAB
Sub-THz frequencies	Precision Demand

Solutions

Progress

Define Objective & Theoretical Knowledge

First Version

Simulations & Midterm Results

Defensive Algorithm

Directional Error Specifications

Final Software Product

Conclusions & Future Work

With Phased Array Nulling we can **evade physical DoS attacks** on LEO satellites in the **sub-THz** band, even with shift inaccuracies.

Our solution shows excellent results as an add-on defensive algorithm for future satellites.

Physical real-world experiments should be done to confirm our findings. We predict good results with improved defensive capability.

Deviation must be maintained under 0.2^{o} to avoid low SNR. We suggest future experiments with Liquid Crystal Phase Shifters to maintain low error.

“A WELL-DESIGNED ANTENNA ARRAY ALLOWS THE BROADCAST POWER TO BE DIRECTED TO WHERE IT IS NEEDED MOST”

THANK YOU

Ofir & Yaara