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SpaceX Starlink

Inside Satellite Dish

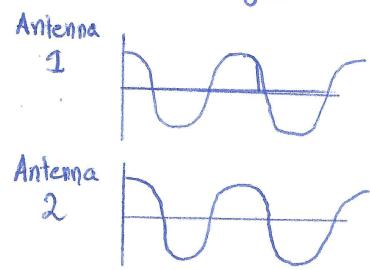
- TV dish uses parabolic reflector to focus electromagnetic waves (TV signals) sent from broadcast satellites (35,000 Km from Earth)
 - can only receive signals, not send data
- Dishy sends/receives data from Starlink Satellite (550 Km from Earth)
 - 60x closer than TV satellites
 - beams between Dishy & Satellite need to be tight & powerful
 - TV signals propagate ~~as~~ ^{than} large fans to land masses larger N. America
 - Starlink satellites need to be in Low Earth Orbit (LEO) to provide 20 ms latency (delay) → critical for strong internet connection
 - Coverage of Starlink is much ~~smaller~~ \therefore 10,000+ satellites at LEO are needed for strong connection

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Phased Array Beam Steering

Next Page

- Array of 1280 antennas and we feed all w/ same 12 GHz signal (to create laser beam)
- Must angle beam to aim directly at Starlink Satellite

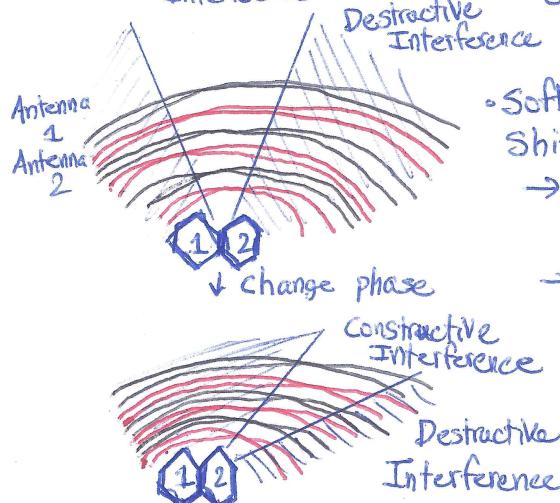


Initially: Feeding same signal to each antenna → in phase

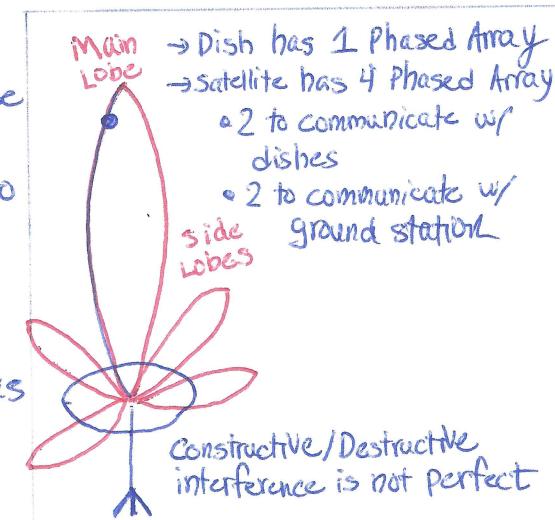
- Amplitude of signal: Change power to antenna (signal is stronger or weaker)
- Frequency: Amount of wavelengths (peaks/troughs) per second
- Phase: Shift signal left or right

To use phase shift to angle beam directly at satellite: phase shift signal sent to one antenna w.r.t other antenna
 → as a result, the timing of peaks/troughs emitted from one antenna, is different from the other

Constructive Interference Destructive Interference → By continuously changing phase of signal sent to antenna → can create a sweeping zone of Constructive Interference

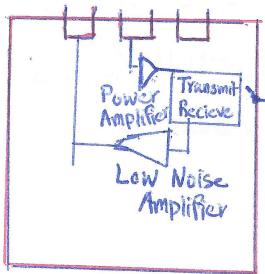


- Software calculates required phase shift for each ~~antenna~~ antenna
- Phase shift results are sent to Beamformers
- Each Beamformer controls 32 Front End Modules (FEM)
- Each FEM controls 2 antennas



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Inside Front End Module



Satellite
27,000 Km/hr

Feed line
To ~~transmit~~
turn off 12 GHz
signal

Phased Array to send/receive
Electromagnetic waves that
are angled to/from the
Starlink Satellite

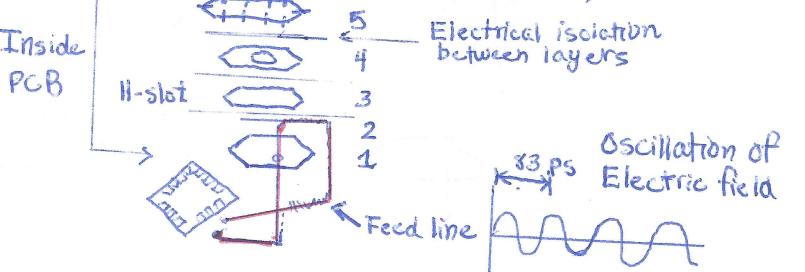
550 Km

- Movement of E field from one side of patch to the other
- Generates a Magnetic field \perp to E field vector
- Propagates an Electromagnetic wave to travel outwards

Aperture Coupled Patch Antenna (6 layers)

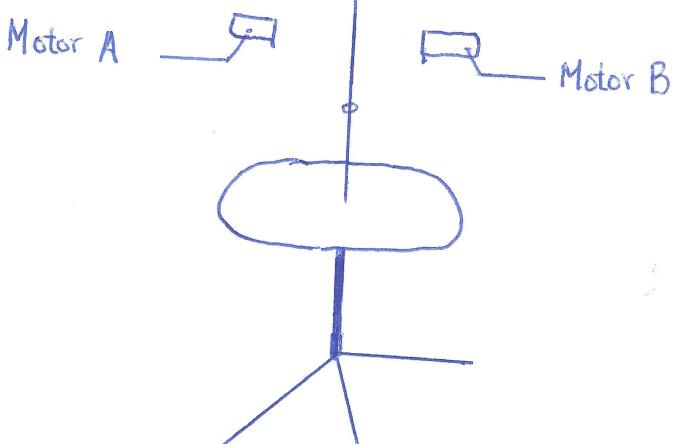
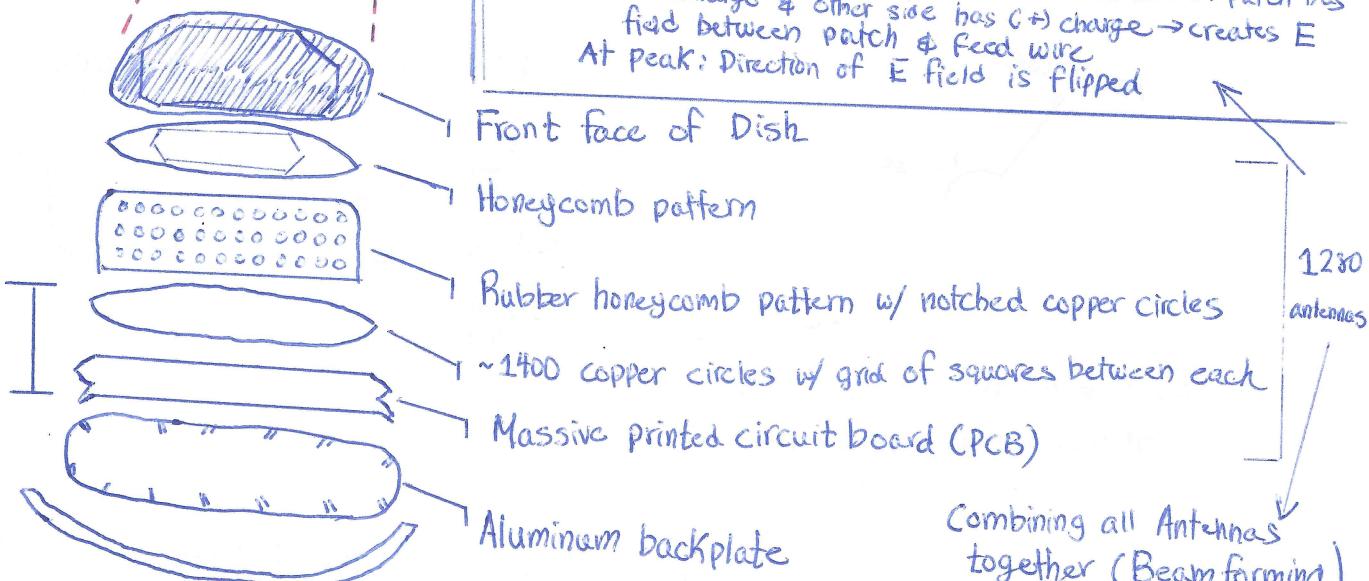
→ Each antenna is arranged in hexagonal, honeycomb pattern

→ Each stack of copper circles is a single antenna controlled by the PCB

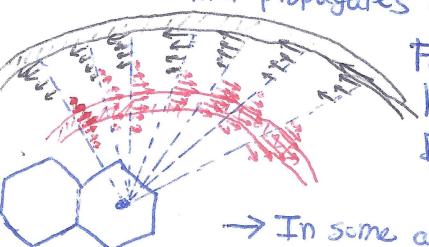


At trough: Zone of (-) charge to feed wire
at end of feed wire → One side of patch has (-) charge & other side has (+) charge → creates E field between patch & feed wire
At peak: Direction of E field is flipped

Copper circles
on top face
of PCB



→ 1 antenna generates an EM wave that propagates outwards (balloon)



Form Beam with
high Intensity &
Directionality to
Reach Space

→ In some areas, E fields point together in same direction w/ overlapping peaks

→ $\rightarrow + \rightarrow$ = \rightarrow Constructive
→ $\leftarrow + \leftarrow$ = \leftarrow Interference

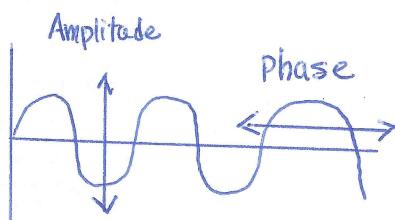
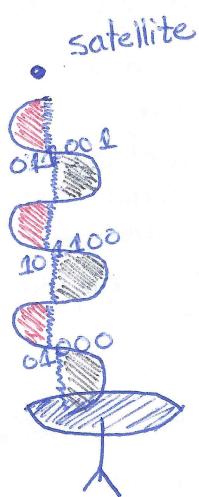
→ $\rightarrow + \leftarrow = 0$ Destructive
→ $\leftarrow + \rightarrow = 0$ Interference

→ In some areas, opposite w/ one peak on one trough → cancel out
interference becomes more focused (Beamfront)

→ By adding more antennas, the zone of constructive

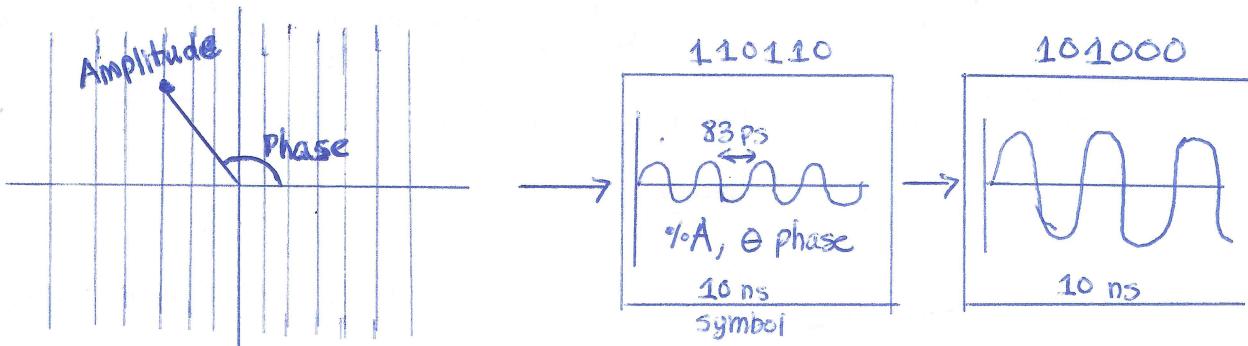
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Information Transfer from Dish to Satellite



Amplitude Modulation + Phase Modulation = Assign 6 bit binary values to each combination/permuation of Amplitude/Phase (64 different permutations)

Constellation Diagram



Each 6 bit grouping is called "symbols" and last 10 ns

64 QAM (Quadrature Amplitude Modulation): Technique of sending 6 bit values using variations of Amplitude & Phase

$$\text{Nanosec} = 1 \times 10^{-9} \text{ s}$$

$$\text{Picosec} = 1 \times 10^{-12} \text{ s}$$

90 million symbols/second

540 Mbits/second