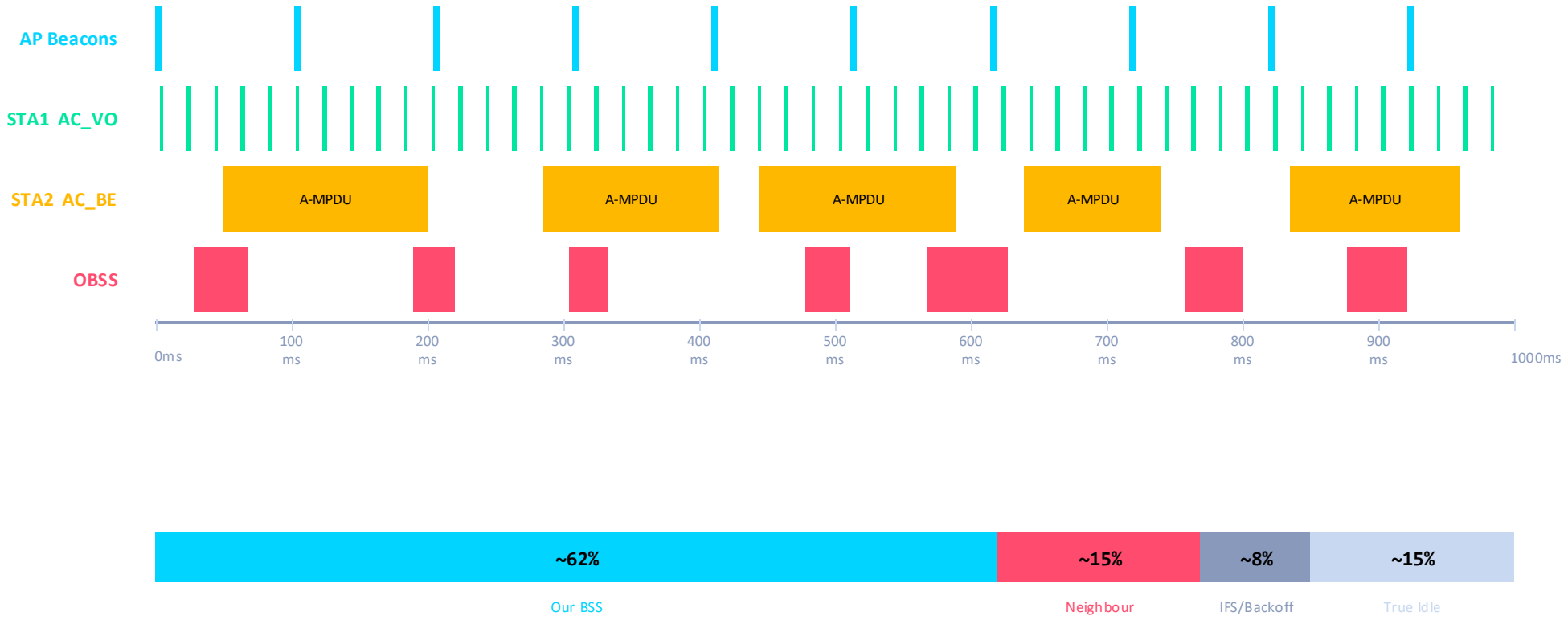
WI-FI IN SLOW MOTION

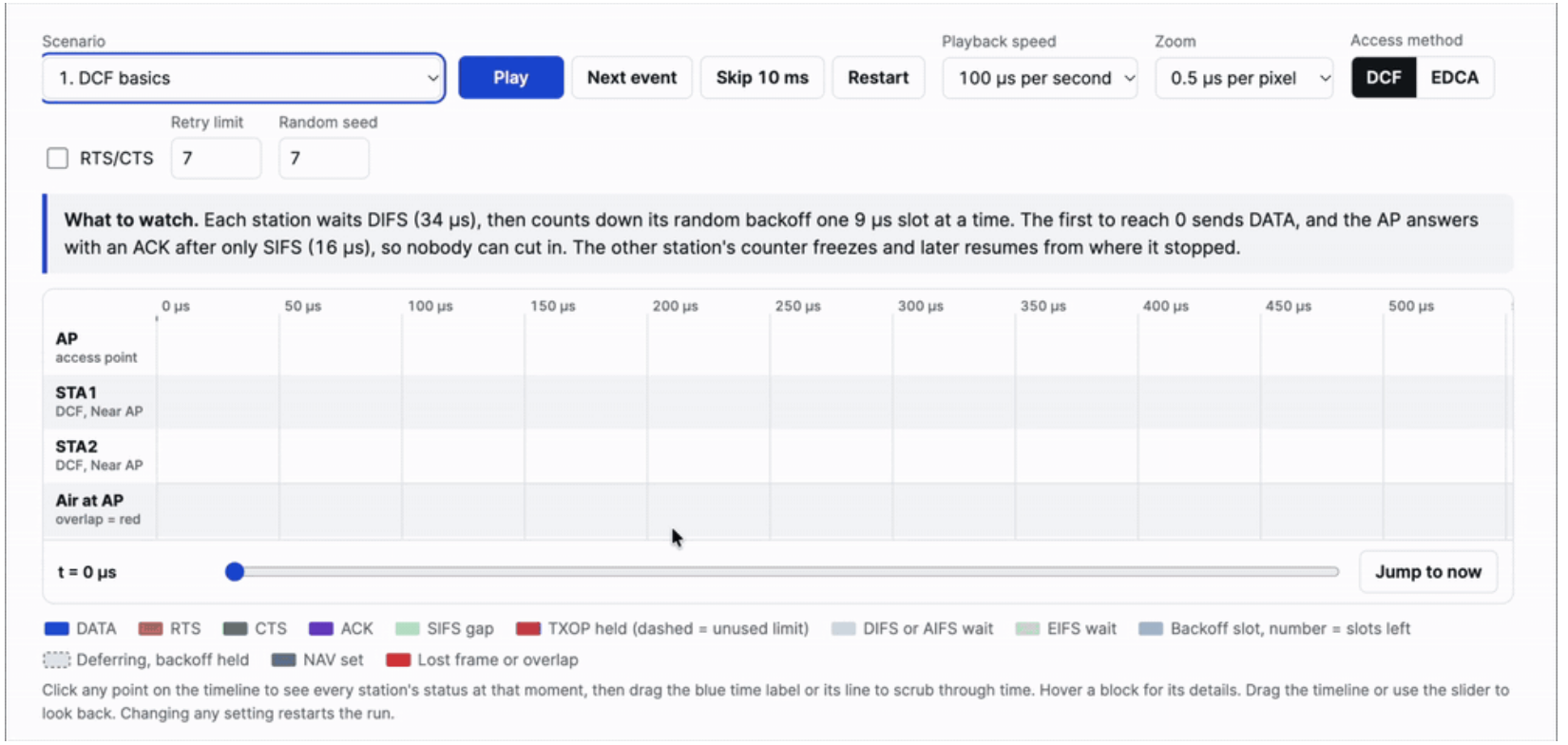
THE NANOSECOND TIMELINE

Chris Carr

TYPICAL WIRELESS COMMUNICATION



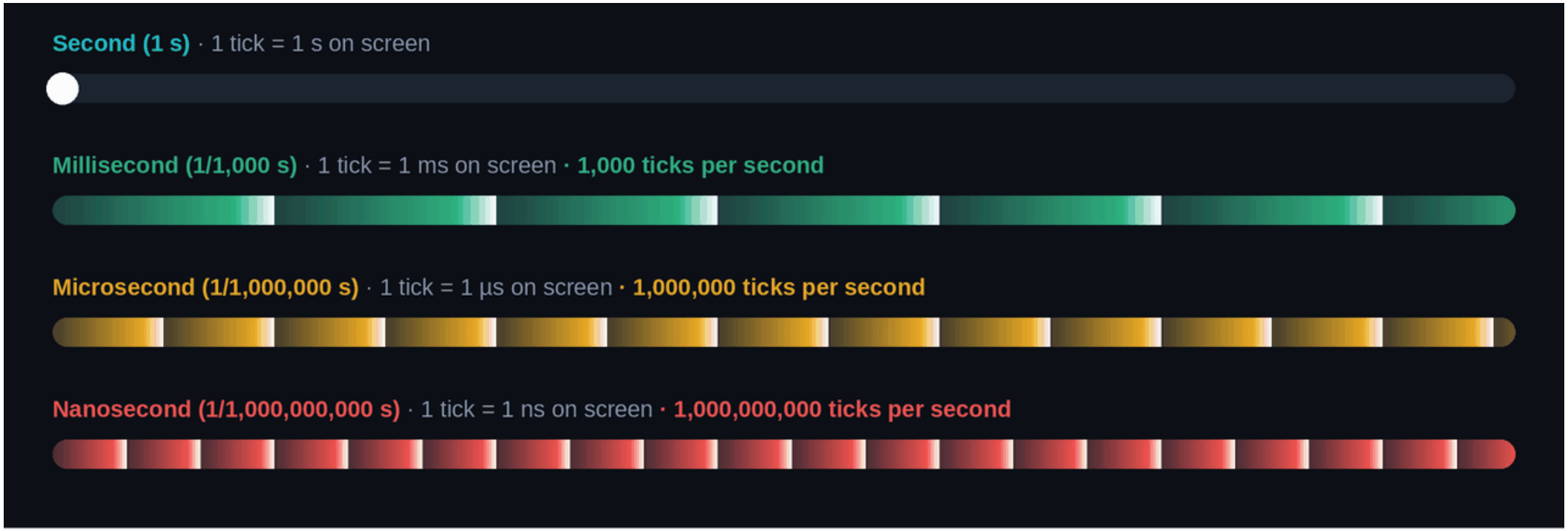
TYPICAL WIRELESS COMMUNICATION



https://learnwifi.siamwireless.com/wifi-medium-access-sim/

WHAT IS A NANOSECOND?

WHAT IS A NANOSECOND?



SECONDS	MILLISECONDS	MICROSECONDS	NANOSECONDS	LIGHT DISTANCE
0 s	5 ms	181 µs	324 ns	0.0 cm

Standard (real time): seconds tick at their normal pace while milliseconds race ahead. Microseconds and nanoseconds are far too fast to see.

Standard | Ultra slow | Super slow-mo | Super duper slow-mo

WHAT IS A NANOSECOND?



SECONDS	MILLISECONDS	MICROSECONDS	NANOSECONDS	LIGHT DISTANCE
0 s	0 ms	5 µs	181 ns	0.0 cm

Ultra slow (1,000× slower): a millisecond now takes a full second to tick. Microseconds race ahead, nanoseconds blur, and seconds barely move.

Standard | **Ultra slow** | Super slow-mo | Super duper slow-mo

WHAT IS A NANOSECOND?

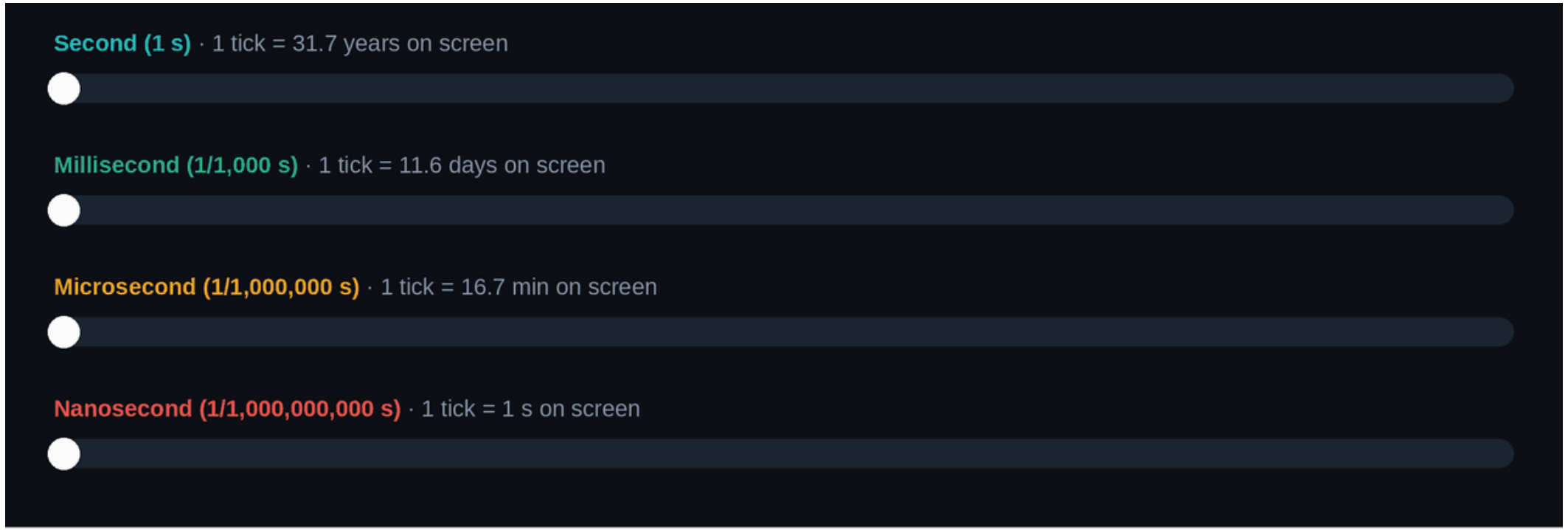


SECONDS	MILLISECONDS	MICROSECONDS	NANOSECONDS	LIGHT DISTANCE
0 s	0 ms	0 µs	5 ns	0.0 cm

Super slow-mo (1,000,000× slower): a microsecond now takes a full second to tick. Nanoseconds spin too fast to see, while seconds and milliseconds are effectively frozen.

Standard | Ultra slow | **Super slow-mo** | Super duper slow-mo

WHAT IS A NANOSECOND?



SECONDS	MILLISECONDS	MICROSECONDS	NANOSECONDS	LIGHT DISTANCE
0 s	0 ms	0 µs	0 ns	0.0 cm

Super duper slow-mo (1,000,000,000× slower): a nanosecond now takes a full second to tick. A microsecond takes about 17 minutes, a millisecond almost 12 days, and a single second would take over 31 years.

Standard | Ultra slow | Super slow-mo | **Super duper slow-mo**

WHAT TAKES A NANOSECOND?

Item	ns	µs
Slot (11b)	20,000	20
Slot (11a/g short, n, ac, ax)	9,000	9
SIFS (2.4 GHz)	10,000	10
SIFS (5 / 6 GHz)	16,000	16
PIFS (5 GHz)	25,000	25
DIFS (5 GHz)	34,000	34
DIFS (2.4 GHz, 9 µs slot)	28,000	28
DIFS (11b)	50,000	50

THE SYMBOL

The Symbol

Standard	Useful symbol (ns)	Total symbol (ns)	Total (µs)
802.11a/g	3,200	4,000	4.0
802.11n/ac, long GI	3,200	4,000	4.0
802.11n/ac, short GI	3,200	3,600	3.6
802.11ax/be, 0.8 µs GI	12,800	13,600	13.6
802.11ax/be, 1.6 µs GI	12,800	14,400	14.4
802.11ax/be, 3.2 µs GI	12,800	16,000	16.0

The Symbol – Guard Interval

Standard	Guard interval	ns	µs
802.11a/g	Long GI	800	0.8
802.11n/ac (Wi-Fi 4/5)	Long GI	800	0.8
802.11n/ac (Wi-Fi 4/5)	Short GI	400	0.4
802.11ax/be (Wi-Fi 6/7)	Short	800	0.8
802.11ax/be (Wi-Fi 6/7)	Medium	1,600	1.6
802.11ax/be (Wi-Fi 6/7)	Long	3,200	3.2

What is a Guard Interval??

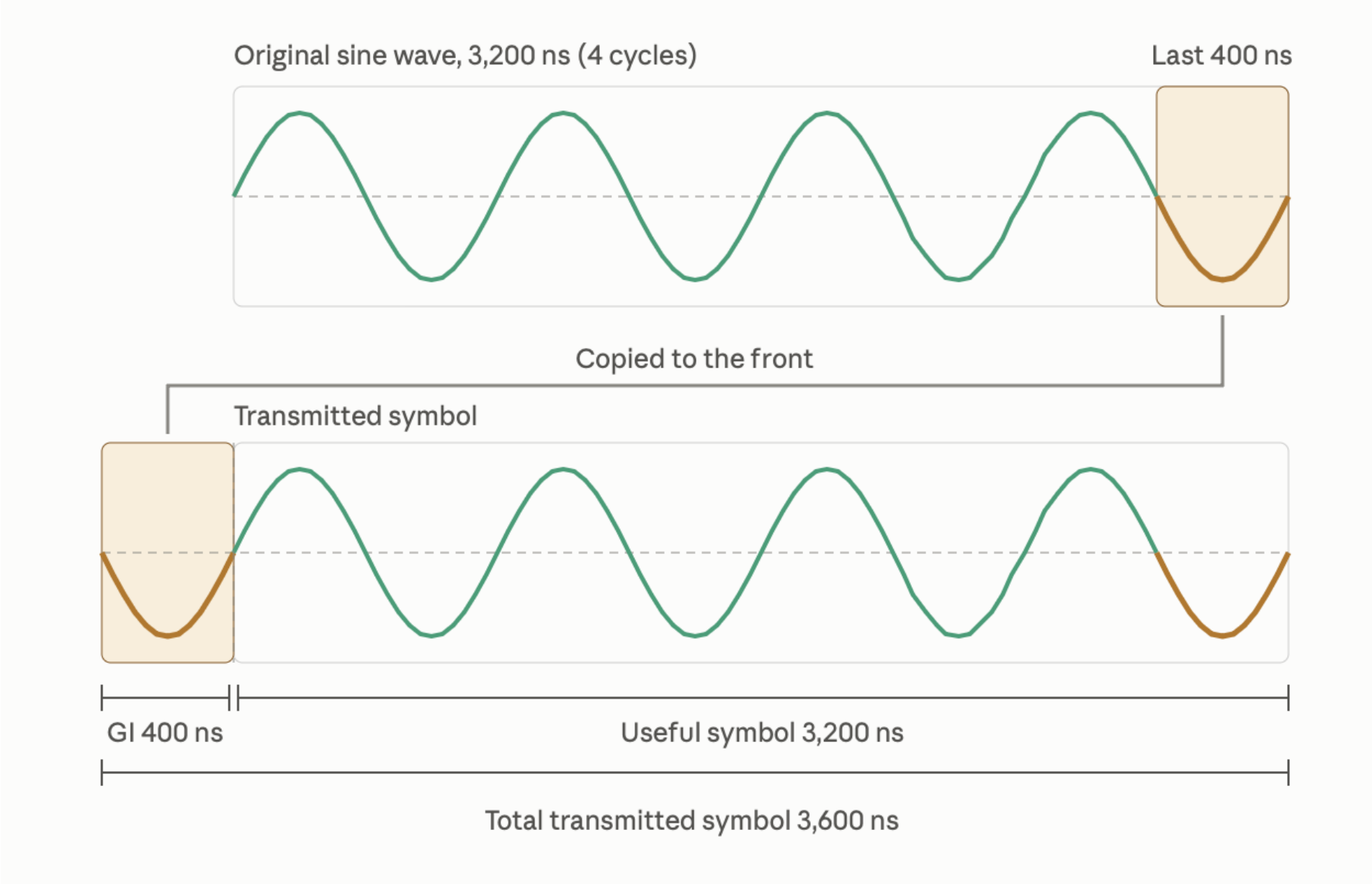
It’s blank space…

…right??

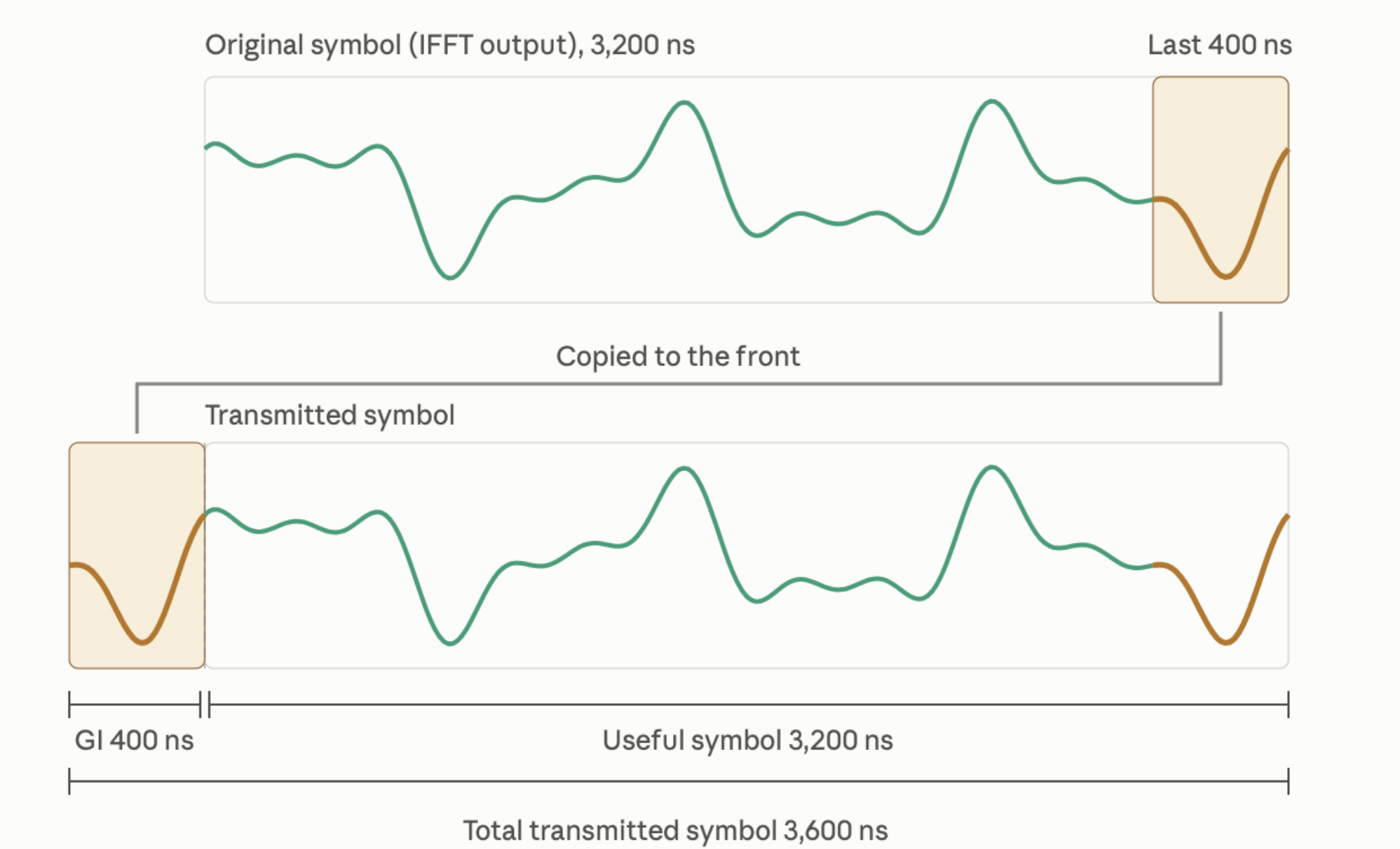
The Symbol – Phase Shock



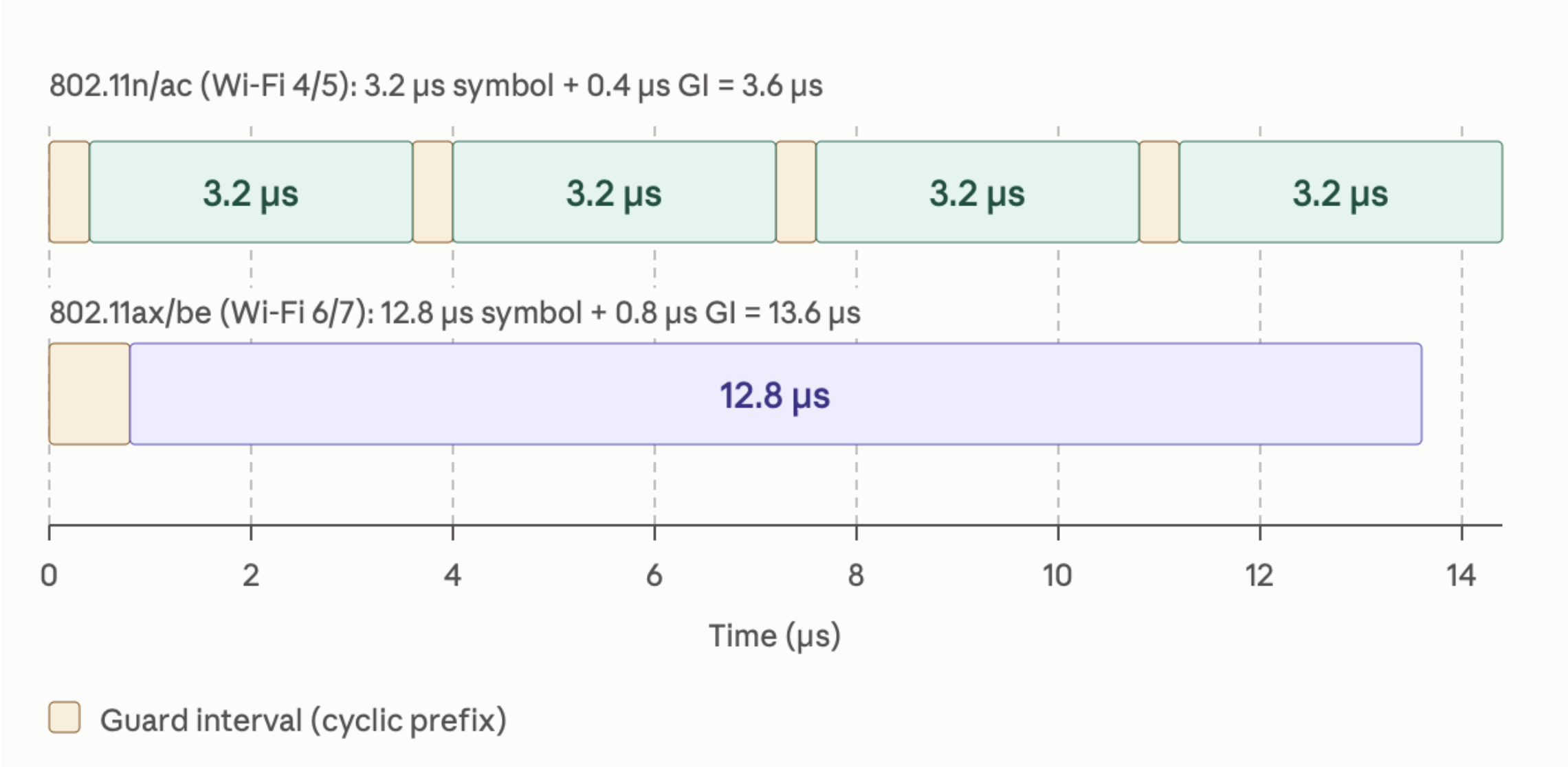
The Symbol


Original sine wave, 3,200 ns (4 cycles)
Last 400 ns
Copied to the front
Transmitted symbol
GI 400 ns
Useful symbol 3,200 ns
Total transmitted symbol 3,600 ns

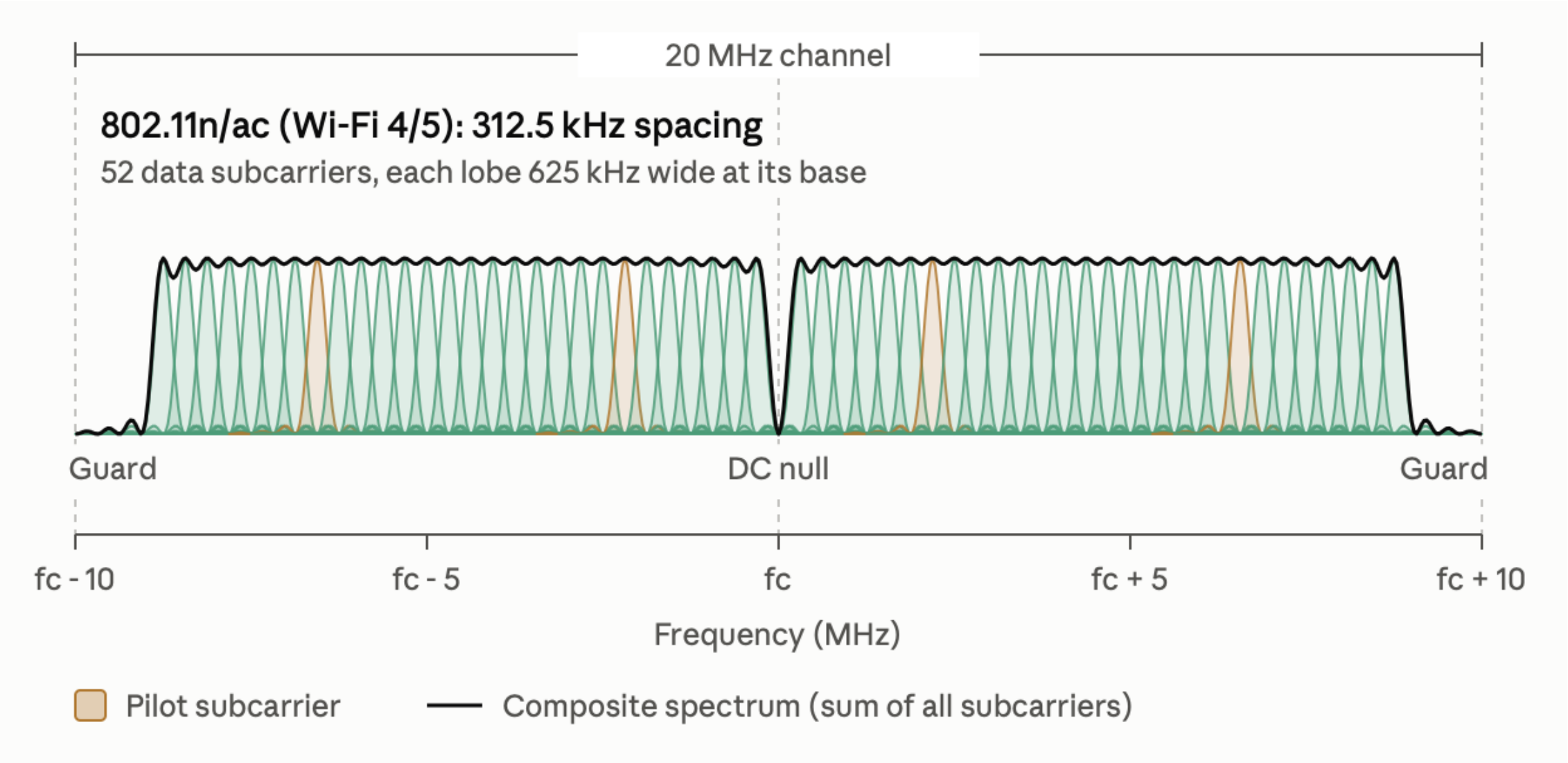
The Symbol


Original symbol (IFFT output), 3,200 ns
Last 400 ns
Copied to the front
Transmitted symbol
GI 400 ns
Useful symbol 3,200 ns
Total transmitted symbol 3,600 ns

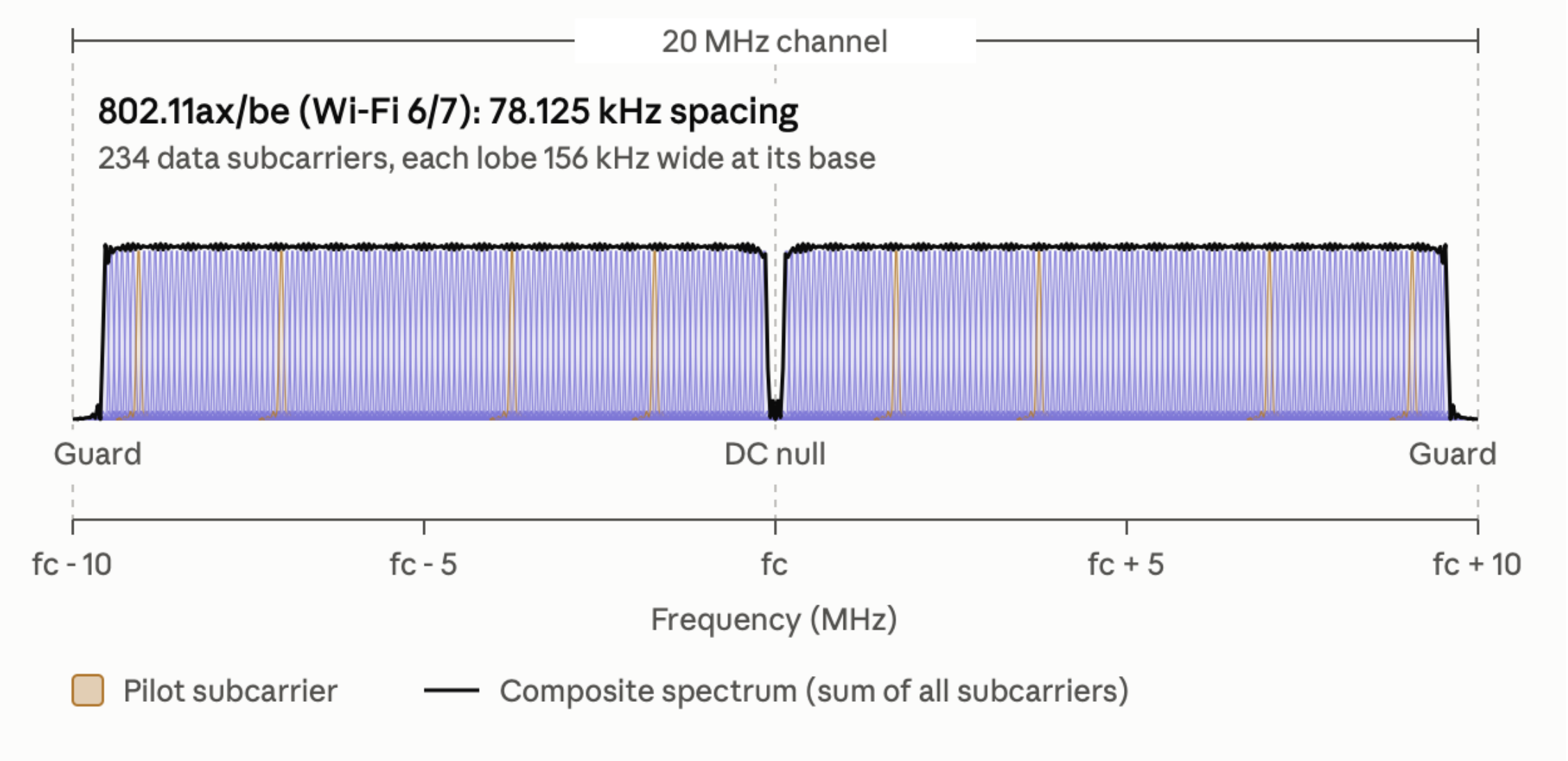
The Symbol


802.11n/ac (Wi-Fi 4/5): 3.2 µs symbol + 0.4 µs GI = 3.6 µs
3.2 µs
3.2 µs
3.2 µs
3.2 µs
802.11ax/be (Wi-Fi 6/7): 12.8 µs symbol + 0.8 µs GI = 13.6 µs
12.8 µs
0
2
4
6
8
10
12
14
Time (µs)
Guard interval (cyclic prefix)

Subcarriers



Subcarriers/Tones



IN SUMMARY

- Guard Intervals aren’t blank space
- The end of a symbol is used at the start as a Guard Interval
- Longer symbols enable more subcarriers
- Chipset Manufacturing must involve Wizardry

- Thank you, Ed

THANK YOU

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