**Twister Outline 2021**

**Slide**

Introduce Myself

Purpose of presentation: A crash-course for some of the new kids, and a refresher for the rest of us.

PLEASE ASK QUESTIONS! This is instructive, not so much a research presentation.

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First up: what’s with the whole I/Q thing anyway? Imaginary signals seem… wrong.

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1. Properties of a cosine wave: phase, amplitude, frequency.
2. A more general way to see it is just amplitude and phase; **frequency is the rate of change of phase with respect to time**.
3. **Any real signal can be described with these two parameters** (amplitude and phase as functions of time).
   1. You may recognize that this is the description of a curve in polar coordinates.

**Slide**

Polar to cartesian conversion. This should be familiar.

If you have a handle on this, you’ve pretty much got a handle on the whole IQ thing.

The whole imaginary thing is the last piece missing, and it’s a mathematical convenience.

**Slide**

Euler’s formula. Very beautiful, very useful.

As you can see, it’s the same thing: phase/amplitude = “cartesian coordinates” = a pair of orthogonal sinusoids. That pair is called the I and Q channels.

However, by making one of the two components (y) complex, we can represent the whole thing as a single number.

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Again, Euler’s formula shows how amplitude and phase can be expressed as a pair of quadrature sinusoids, and all as a single compact complex number.

That’s what the I and Q channels are. You can think of them as the cartesian coordinate versions of a signal defined by phase and amplitude.

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Read the slide.

**Slide**

Any Questions so far?

**Slide**

Once you understand how the infamous “I and Q” channels correspond to amplitude and phase, we’re ready to discuss modulations schemes.

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The whole point is to send information.

Information is conveyed by unexpected or unpredictable changes. (The “unpredictableness” of something is called its *entropy* in information theory).

There are two things we can change on a sinusoid: Amplitude, and Phase.

Ergo, amplitude modulation, phase modulation, or both.

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At this point, it’s time to introduce a “tool” called a constellation diagram.

It’s a plot used to visualize quadrature signals.

It plots I versus Q. (amplitude and phase)

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Simple example to start off: on/off keying.

Signal is on or off. Each symbol carries one bit.

You’ll notice that since only the amplitude is changing, we don’t need both I and Q to describe this signal. There’s no phase changes, only amplitude.

Simple, but not the best.

**Slide**

If you like ASK, here’s more of it. Again, simple.

Use multiple levels to carry more than 1 bit.

But there’s a lot more space on the constellation diagram, and the I channel is getting lonely.

**Slide**

This is BPSK. It’s like ASK, but better (noise tolerance)

The I channel is still lonely. Let’s move on to some more advanced modulations.

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Describe QPSK.

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It’s like QPSK, but with more symbols.

More symbols mean more data per symbol. This is usually a good thing, but it requires higher SNR.

Pure phase modulation is better than pure amplitude modulation, but the real deal comes in when you change them moth at once.

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M-QAM.

You can take this as far as you want. 1024-QAM is a thing.

Higher bits per symbol means higher spectral efficiency – you can send more data ever second per unit bandwidth.

And speaking of bandwidth…

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Let’s talk about bandwidth.

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Discuss time/bandwidth relations.

Implications for communications? More bandwidth is better.

This is one of those “big concepts” that you really want to latch onto.

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Alas, we can’t have all the bandwidth. People complain.

So we need to limit it.

This means the waveforms I’ve been showing aren’t realistic. They have sharp changes between symbols. It turns out those blazingly fast transitions aren’t necessary.

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Discuss the filters and Fourier transform pairs.

Note: The SINC pulses here should be much broader.

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Explain how sampling works.

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Make sure they get orthagonality.

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Follow slide.

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Lastly, the question that puzzles just about everybody the first time they encounter it: What’s OFDM?

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Good news: It’s not complicated at all if you’ve got the time/frequency conversion thing down.

And also if you understand pulse shaping.

And a little bit of IQ convention.

Explain the slide.

**Slide**

Hit the takeaway: Reverse time and frequency roles.

More efficient versions of OFDM use I/Q stuff to pack more than one bit into each spectral window.

Questions?

Extra: Dynamic range, ISI immunity (cyclic prefix)

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Any more questions at all?

**If you wanna see my research, I have more slides if y’all want a quick overview**.