FIT9137 Applied Week-7

Topics

- Physical layer: Digital and Analogue Modulation
  - FM, AM, and PM encoding
  - Constellation diagrams
  - Unipolar, NRZ-I, Manchester encoding

Covered Learning Outcomes:

- Analyze and formulate the functions and architectures of (wireless) local area networks, wide area networks and the Internet.
- Examine networks using the underlying fundamental theories, models and protocols for data transmission.

Instructions:

- One of the main purposes of an applied session is to build the learning community, create connections and include the learners. The other goal is to give and receive feedback from your peers and or your tutors.
- Form groups of 2 students (peers) to work through the exercises. If met a problem, try to solve it by asking direct questions to your peer. If the issue was not solved within peers, ask your tutor. If did not get a chance to solve the problem during your applied session with your peer or tutor, jump into one of many consultation hours and ask any of the tutors to help you. Please visit the "Teaching Team and Unit Resources" tile in the FIT9137 Moodle site.

A. Constellation Diagrams

In this activity you will learn a different way of representing amplitude and phase modulation with multiple bits per symbol. Let's consider *phase* modulation first and assume that we want to modulate using 2 bits per symbol. This requires 4 different phases. We must decide which symbol shall correspond to which phase, which we write down in an encoding table:

Bits	Phase ϕ (Radians)
00	$45°\ (\frac{\pi}{4})$
01	$135°\ (\frac{3\pi}{4})$
10	$225°\ (\frac{5\pi}{4})$
11	$315°\ (\frac{7\pi}{4})$

Remember from the week 6 recorded lecture videos we have a sine wave with phase ϕ has the form $A \times sin(2\pi f x + \phi)$ where A is the amplitude and f is the frequency. An alternative representation of an encoding plots each symbol as a point on a graph, such that the amplitude is the distance from the origin (the x=0, y=0 coordinate), and the phase is the angle.

Let's say we have a sine wave with amplitude 1 and phase 45° (or $\frac{\pi}{4}$). The following graph shows this as a point at a distance of 1 unit from the origin and an angle of 45°:

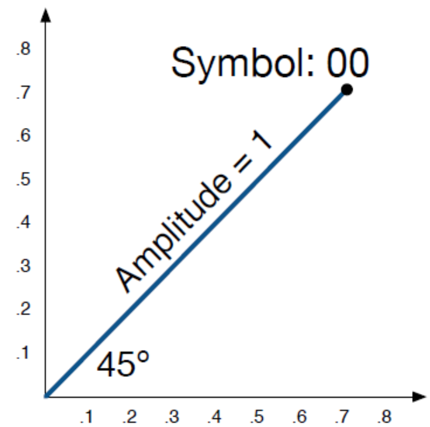

Figure 7: How Phase and Amplitude of a symbol is represented in constellation diagram

Let's look at a graphical representation of all four phases from our table (assuming amplitude 1):

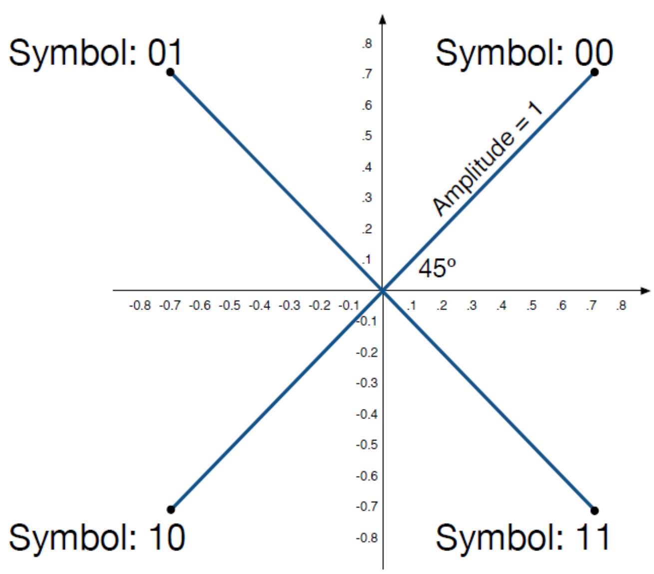

Figure 8: 2-bit Phase Modulation constellation diagram

This diagram is called a constellation diagram. It simply maps each symbol to a position in 2-dimensional space.

Designing Constellations

When designing encodings, we often actually start with the constellation diagram and then convert it to an encoding table.

Example

Let's assume we want to design an encoding with eight different symbols. We just pick eight points in a diagram, and then extract the amplitudes and phases directly from the diagram. Usually, we will put points as far away from each other as possible, and in [Analogue Modulation Encoding] exercise, below, you should think about why that's a good idea.

So how can we get the amplitude and phase of a point in the diagram? It's simple trigonometry. Let's take the point in the bottom right corner in the diagram below. Its coordinates are (0.5, -0.7).

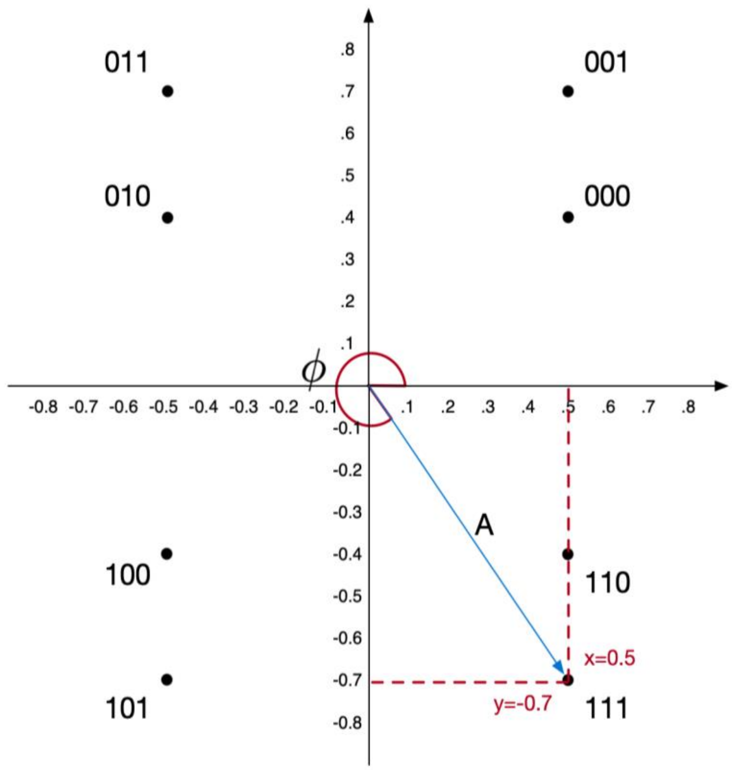

Figure 9: 3-bit Phase and Amplitude Modulation constellation diagram

Amplitude: remember it's the distance from the origin. We can easily get it using Pythagoras: $A = \sqrt{y^2 + x^2}$, so in this case we get $A = \sqrt{(-0.7)^2 + (0.5)^2} = 0.86$.

Phase: this is the angle of the vector through the point (the blue arrow), shown as the red sliced pie. We can get $\phi = tan^{-1}(\frac{y}{x})$ which in our concrete case is $\phi = tan^{-1}(\frac{-0.7}{0.5}) = -0.95$ radian $= -54.5° = 305.5°$ (in 0 to 360 positive values). This in fact is the angle of the blue vector to the x axis.

We now have two ways of constructing a modulation encoding:

- we can start from an encoding table,
- or we can start from a constellation diagram.

From the encoding table, we can directly see the amplitude and phase for a sine wave. From a constellation diagram, we can get the amplitude and phase angle using simple trigonometry.

If we have to encode many symbols and we want to use a combination of phase and amplitude modulation, it is often easier to start with a constellation diagram.

The plot at https://www.desmos.com/calculator/bfbnguc20v shows you how to draw constellation diagrams using the graph plotter.