Amplitude, Wavelength, Period, and Frequency

Imagine that the dots moving up and down are creating the waves that are travelling to the right (as we'll see later, this is kind of like how radio waves are created). Here are a few things to notice:

1. The Blue wave is twice as “tall” as the green wave.
2. Both waves are travelling to the right at the same speed.
3. The Blue dot is moving up and down three times as fast as the green dot.
4. The Blue wave is three times as compressed as the green wave.

To quantify these observations more precisely, let's look at a snapshot of both waves frozen in time.

- the **amplitude** is the **vertical** height from the centre of the wave to its highest (or lowest) point. The blue wave has an amplitude of 2 and the green wave has an amplitude of 1.
- the **wavelength** is the **horizontal** distance of one full cycle. The blue wave has a wavelength of 2m and the green wave has a wavelength of 6m.

Now imagine that the animation is in super slow motion and that the waves are actually travelling at the speed of light, which is roughly 300,000,000 metres per second: How many times does each dot go up and down in one second?

Another way of asking that question is: how many full cycles can you fit in 300,000,000 metres (since radio waves travel 300,000,000 metres each second).

- Since the blue wave has a wavelength of 2m, it'll take 150,000,000 cycles to reach 300,000,000 metres. That means that the blue dot oscillates at 150,000,000 cycles per second, or 150,000,000 Hz, or 150 Mhz
- Similarly, since the green wave has a wavelength of 6m, its frequency is 50 Mhz.

So a quick way to relate the frequency f (in MHz) and the wavelength λ (in metres):

<latex> $$ \lambda = \frac{300}{f} \qquad \text{or} \qquad f = \frac{300}{\lambda}$$ </latex>

Note that the reason we're using just 300, instead of 300,000,000 is that we've cancelled 6 of the zeros so that the frequency is in MHz instead of in Hz.

Now, here's a related question: how long does it take for each wave to complete one cycle?

- For the blue wave, we know that it oscillates 150,000,000 times / second, so only one of those time would be 150,000,000th of a second. That is: $\frac{1}{150,000,000}\text{s} = 6.67 \times 10^-9 \text{s} = 6.67 \text{ns}

Look at the following two waves. How are they different?

At first sight:

1. the first one is “taller” than the second one. That is, it goes up and down higher and lower.
2. the first one is also “longer” than the second one. That is, it stretches sideways more. It's not as “tight”.

These two observations can be quantified very precisely as:

1. the *amplitude*: **vertical** height from the centre of the wave to its highest (or lowest) point.
2. the *period*: **horizontal** length of one complete cycle.

So the previous two waves have:

1. Amplitude = 2, Period = 0.05 ms
2. Amplitude = 1, Period = 0.02 ms

The amplitude is normally related to the strength of the signal (like the volume for sound).

Since the period (*T*) is the amount of time it takes to complete one cycle, and the frequency (*f*) is the number of cycles in one second, the period and the frequency are inverses of each other:

<latex> \qquad $$f = \frac{1}{T} \qquad \Leftrightarrow \qquad T = \frac{1}{f}$$</latex>

<box 80% blue> In this course, we'll see a few formulas and it'll be tempting to memorize them but let's instead understand what they really mean... </box>

For example:

- if the period is half a second, we can fit 2 full cycles in one second.
- If the period is a quarter of a second, the frequency is 4.
- If the period is a tenth of a second, the frequency is 10.
- If the period is T seconds, the frequency is $\frac{1}{T}$ ($\frac{1}{0.5} = 2, \quad \frac{1}{0.25} = 4, \quad \frac{1}{0.1} = 10$)

Right?

So for the previous two waves, the frequencies would be:

- <latex>$$f = \frac{1}{0.05 \text{ ms}} = \frac{1}{0.00005 \text{ s}}$$</latex> = 20,000 Hz = 20 kHz
- <latex>$$f = \frac{1}{0.02 \text{ ms}} = \frac{1}{0.00002 \text{ s}}$$</latex> = 50,000 Hz = 50 kHz

Recall that *Hz* means “cycle per seconds”. That's why when we divide a number of cycles by time, we get Hertz.

Let's now look at three different ways to encode a signal on a radio wave.

Fix Me!: add $f=\frac{c}{\lambda}$