

Course material

Course:

## Digital Signal Processing II

Video:

### 2.1.5.d Demodulation revisited

Concepts (extracted from automatically generated subtitles):

**Signal x. Modulated signal. Main minus  $\pi$ . Unwanted high frequency components. Cosine of  $\omega$ . Low pass filter. Main signal. Second component. High frequency. Demodulated signal. Minus  $\omega$ . Ideal filters. N times. Single period. Original modulated spectrum.**



[to video sequence search](#)  
(within Digital Signal Processing II.)



[to video](#)

Center for Digital Education. More educational support material here:

<https://exoset.epfl.ch/booc/>

## Demodulation revisited

- ▶ apply sinusoidal modulation to  $x[n]$ :  $y[n] = x[n] \cos \omega_0 n$
- ▶ demodulate by multiplying by the carrier  $x'[n] = y[n] \cos \omega_0 n$
- ▶ demodulated signal contains unwanted high-frequency components

So now that we have the ideal filters in place, why don't we revisit the demodulation problem that you remember we left somewhat open a few lectures ago.

notes

summary

0m 0s



## Demodulation revisited

- ▶ apply sinusoidal modulation to  $x[n]$ :  $y[n] = x[n] \cos \omega_0 n$
- ▶ demodulate by multiplying by the carrier  $x'[n] = y[n] \cos \omega_0 n$
- ▶ demodulated signal contains unwanted high-frequency components

You remember the story, we applied sinusoidal modulation to an input signal  $x$  of  $n$  to obtain  $y$  of  $n$  which is equal to  $x$  of  $n$  times the cosine of  $\omega_0 n$ .

notes

summary

0m 1s



## Demodulation revisited

- ▶ apply sinusoidal modulation to  $x[n]$ :  $y[n] = x[n] \cos \omega_0 n$
- ▶ demodulate by multiplying by the carrier  $x'[n] = y[n] \cos \omega_0 n$
- ▶ demodulated signal contains unwanted high-frequency components

And we tried to demodulate the modulated signal by multiplying the modulated signal again by the carrier cosine  $\omega_0 n$ .

notes

summary

0m 13s



## Demodulation revisited

- ▶ apply sinusoidal modulation to  $x[n]$ :  $y[n] = x[n] \cos \omega_0 n$
- ▶ demodulate by multiplying by the carrier  $x'[n] = y[n] \cos \omega_0 n$
- ▶ demodulated signal contains unwanted high-frequency components

And we found out that the demodulated signal contained unwanted high frequency components that at the time we did not know how to remove.

notes

summary

0m 20s



## Demodulation revisited

- ▶ apply sinusoidal modulation to  $x[n]$ :  $y[n] = x[n] \cos \omega_0 n$
- ▶ demodulate by multiplying by the carrier  $x'[n] = y[n] \cos \omega_0 n$
- ▶ demodulated signal contains unwanted high-frequency components

Well now we do, so let's look again what happens.

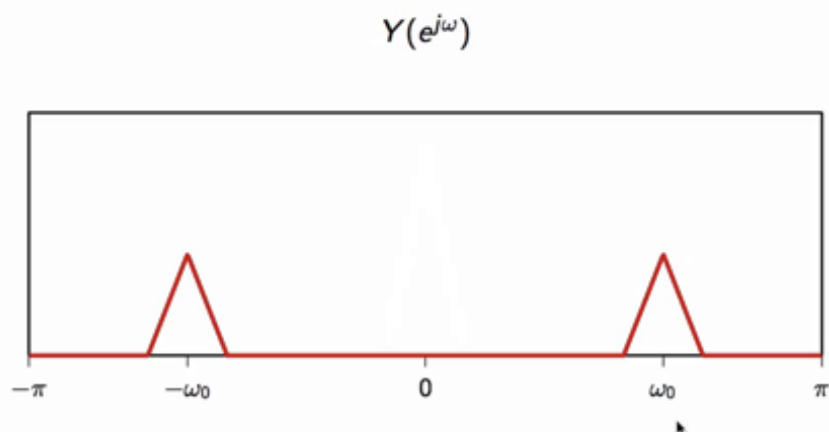
notes

summary

0m 25s



## Demodulation revisited



So we have the spectrum of the signal, we modulate it, and we obtain two copies, half the amplitude, at  $\omega_0$  and  $-\omega_0$ .

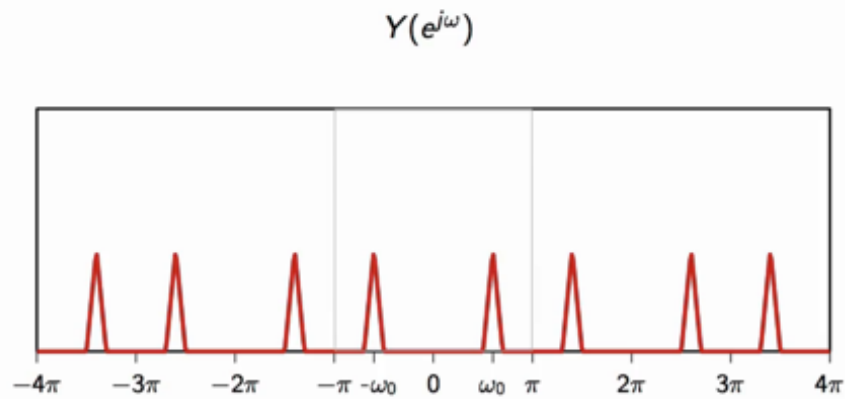
notes

summary

0m 37s



## Demodulation revisited



When we multiply this signal by cosine of  $\omega_0$  again, and we can see this more in detail if we explicitly show the periodicity of the spectrum. So here you have the main minus  $\pi$  to  $\pi$  interval and here you have the repetition.

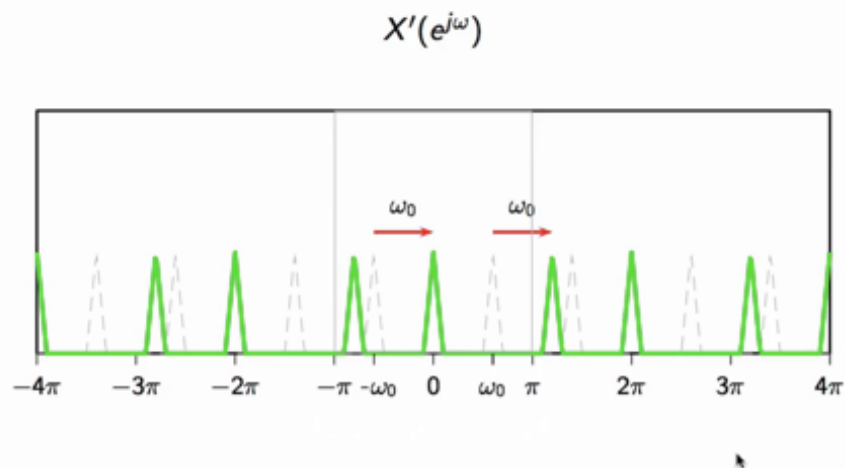
notes

summary

0m 49s



## Demodulation revisited



So we multiply that by cosine of  $\omega_0$  and we get one copy of the repeated spectrum. So we shift to the right by  $\omega_0$ , so you see here in green, whereas with the dashed line you see the original modulated spectrum.

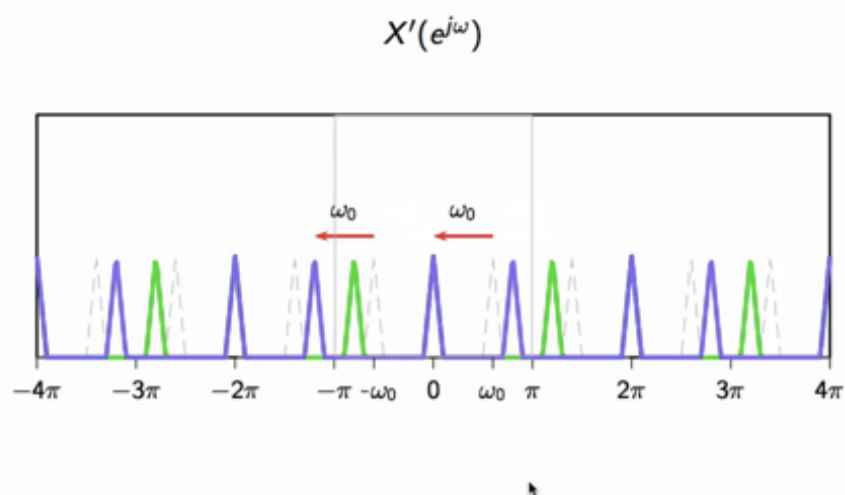
notes

summary

1m 1s



## Demodulation revisited



And the second component would be another copy of the modulated spectrum, this time shifted to the left by  $\omega_0$ .

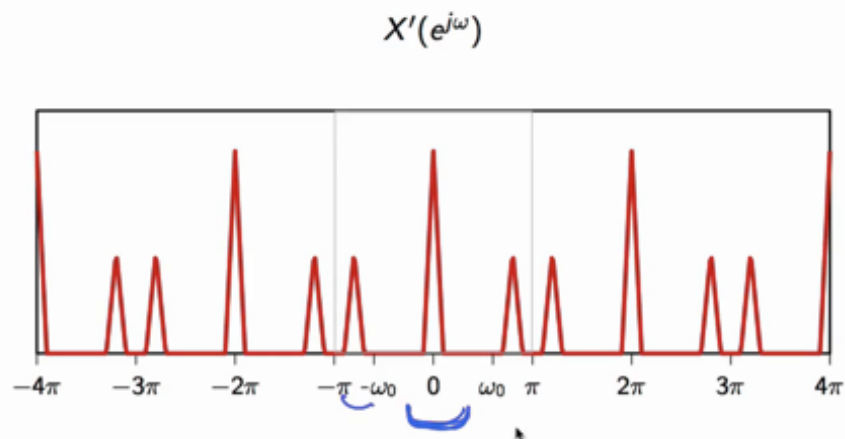
notes

summary

1m 13s



## Demodulation revisited



And so you have the two copies that now you have to sum together and what you get is of course the reconstruction of the original signal centered around 0 and the components at high frequency. So if we go back to the standard visualization of the spectrum over a single period from minus pi to pi,

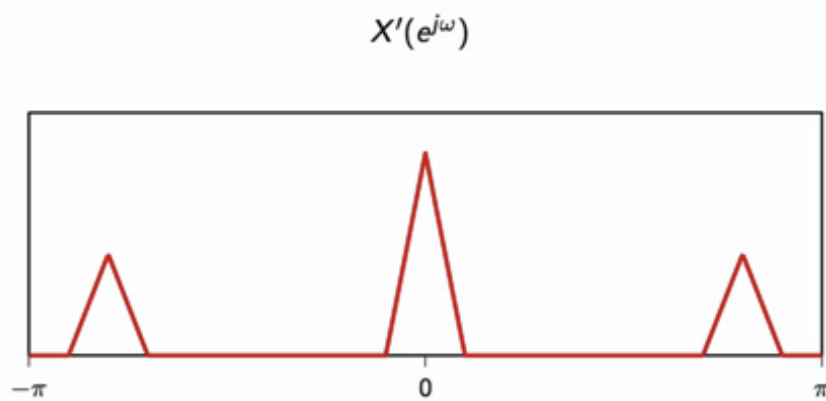
notes

summary

1m 25s



## Solution: lowpass filtering



this is the situation we have to deal with. Well now we know what we need to do at this point is to eliminate this period's components and we can do that easily by using a low pass filter.

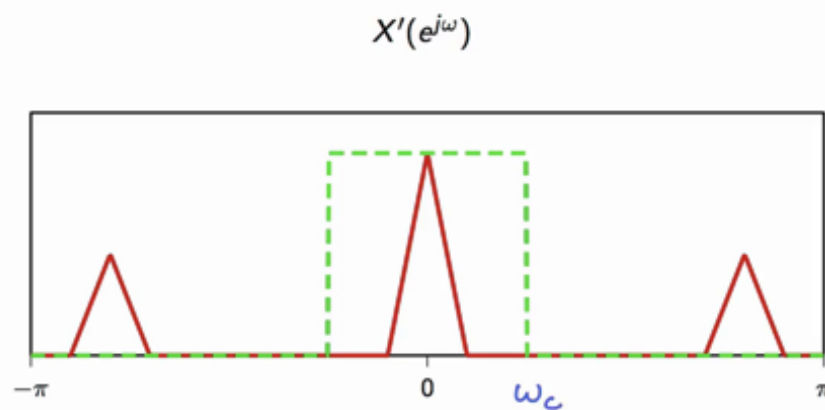
notes

summary

1m 37s



## Solution: lowpass filtering



So we put a low pass filter here, choosing a cutoff frequency  $\omega_c$  that is large enough to include the main signal, the baseband signal, how it's called,

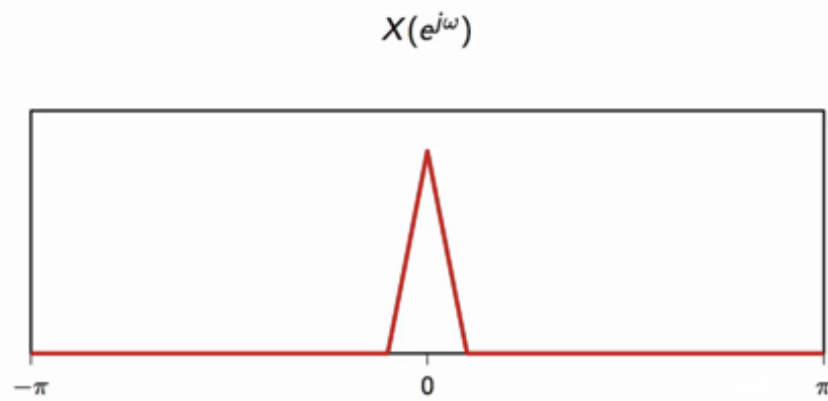
notes

summary

1m 49s



## Solution: lowpass filtering



and small enough in order to kill the high frequency components. And when we do that we obtain the original signal back without any extraneous material.

notes

summary

2m 1s

