

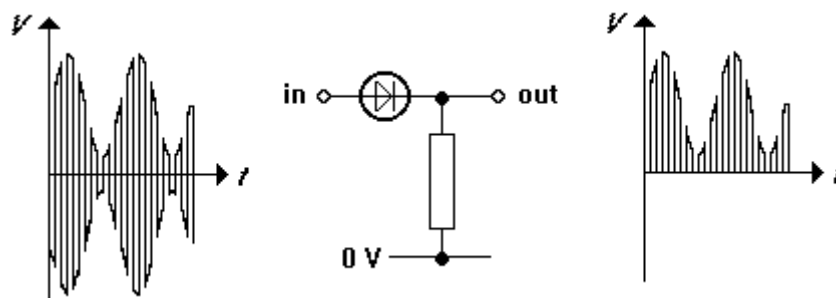
Modulation bandwidths with FSPECTRA

FSPECTRA.XLS is a spreadsheet. It allows you to work out the voltage-time graph (waveform) of a signal if you know the components of its frequency spectrum. You are going to use it to estimate the bandwidth required for a.m. and f.m. signals.

- 1 Open up the spreadsheet. Set all of the amplitudes (a1 to a10) and frequencies (f1 to f10) to 0.0.
- 2 Set amplitude a1 to 1.5 V and frequency f1 to 20 kHz. Press F9. Take a look at the graphs showing the waveform and its spectrum. Does it look like an unmodulated carrier signal at 20 kHz?
- 3 Now add a pair of sidebands at 21 kHz and 19 kHz, each with an amplitude of 0.5 V. Does the result look like a 20 kHz carrier amplitude modulated by a signal at 1 kHz?
- 4 Note the effect of increasing and decreasing the amplitudes of the sidebands, keeping them the same as each other. How does the depth of the modulation depend on the amplitudes of the sidebands?
- 5 Set up each of the sideband pairs shown in the table below. Keep an amplitude of 0.5 V for the sidebands. Measure the period of the modulation each time.

lower sideband	carrier frequency	upper sideband	modulation period	modulation frequency
19 kHz	20 kHz	21 kHz		
18 kHz	20 kHz	22 kHz		
17 kHz	20 kHz	23 kHz		
16 kHz	20 kHz	24 kHz		

- 6 Calculate the modulation frequencies. How are they related to the bandwidth required to carry the modulated signal?
- 7 The diagram shows how an a.m. signal can be demodulated with a diode.



The process of rectification adds the following spikes to the frequency spectrum:
 A spike at 0 Hz, with the same amplitude as the carrier.
 A spike at the modulation frequency with twice the amplitude of the sidebands.

Use FSPECTRA to check this rule for the a.m. signal in step 3.

Electronics Explained: Analogue Transmission

The next set of instructions will give you a feel for the bandwidth required to accommodate frequency modulated carriers.

- 8 Set up a single spike at 7.5 kHz with an amplitude of 2.0 V. This is the unmodulated carrier. Look at its waveform.
- 9 The 7.5 kHz carrier is going to be frequency modulated by a 1 kHz square wave, switching the 7.5 kHz carrier between 5 kHz and 10 kHz. Use FSPECTRA to see what both of these waveforms look like.
- 10 Now set up the frequency spectrum shown in the table. Its waveform should look like a 5 kHz carrier being switched on and off at a rate of 1 kHz.

amplitude (v)	frequency (kHz)
-0.23	2
+0.70	4
+1.10	5
+0.70	6
-0.23	8

- 11 Add the extra components shown in the table below. The result should look like a carrier signal being switched between 5 kHz and 10 kHz at a rate of 1 kHz.

amplitude (v)	frequency (kHz)
+0.23	7
-0.70	9
+1.10	10
-0.70	11
+0.23	13

- 12 You have built up the waveform and spectrum of a frequency modulated signal with the following properties.
 - a carrier frequency of 7.5 kHz
 - a deviation frequency of 2.5 kHz
 - a signal frequency of 1 kHz
- 13 Now build up the waveform and spectrum of an f.m. signal with these properties.
 - a carrier frequency of 15 kHz
 - a deviation frequency of 3 kHz
 - a signal frequency of 2 kHzDoes the waveform look as if it is being switched between 12 kHz and 18 kHz at a rate of 3 kHz? What is the bandwidth required?
- 14 Now restrict the bandwidth to five times the signal frequency. Does this make much difference to the f.m. signal waveform?
- 15 Finally, keeping the bandwidth fixed at 10 kHz, investigate the effect of reducing the signal frequency to 1 kHz and 500 Hz.