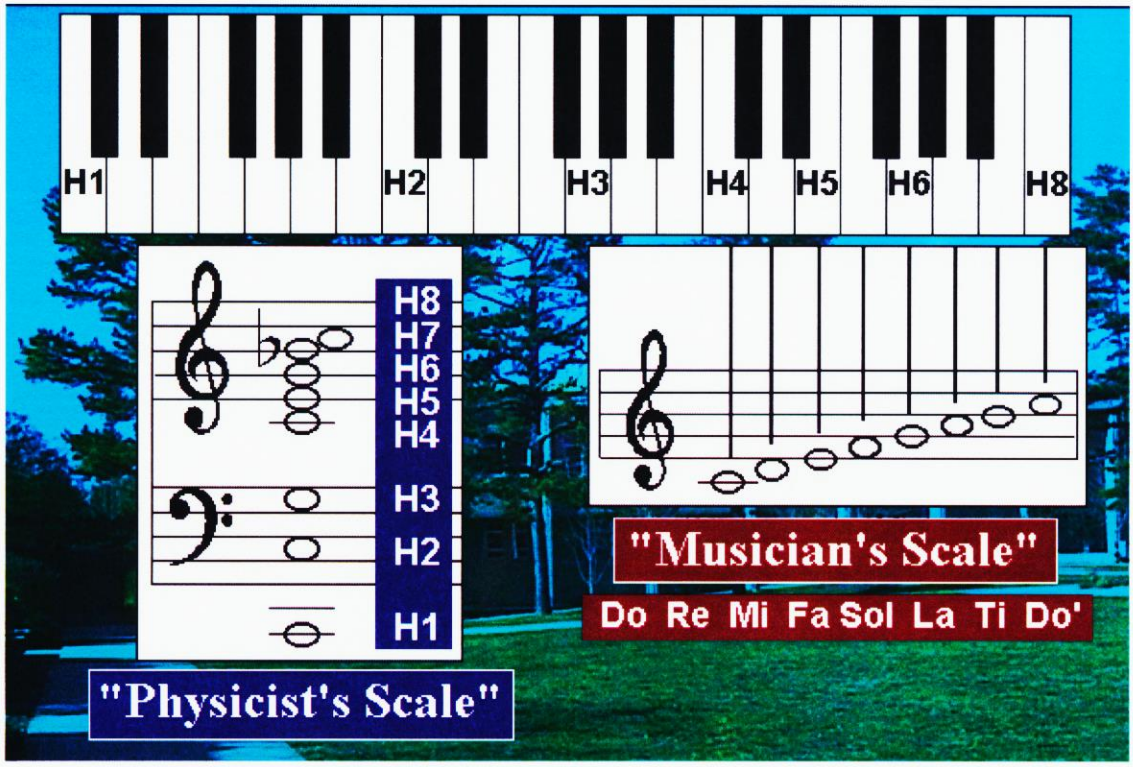
Johannes Brahms (1833-1897), *Academic Festival Overture* (1880). Lived with the Schumanns (Robert and Clara) for a while, "uncle" to the Schumann seven kids.

Also Sprach Zarathustra (1896), Theme for the Movie 2001 (1968).

Use of harmonics at the beginning: brass H2-H3-H4-H5.

Composer: Richard Strauss (1864-1949).



Rimsky-Korsakov (1844-1908) "the resonance of different harmonic parts must be equally balanced."

Peter Tchaikovsky (1840-1893), the usual use of the harmonics in composition – playing many together at the same time to achieve the full satisfying sound. Ex. *Fourth Symphony*. He uses harmonics H1 through H8 except for H7 (the jazzy one).

Complex Wave: any wave that is not a sine wave

Periodic complex wave: periodic wave that is not a sine wave

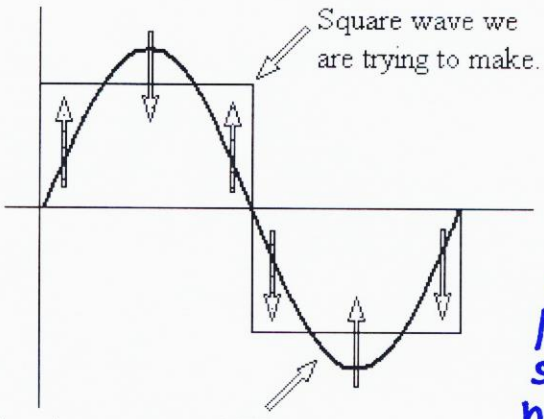
Fourier's Theorem: you can synthesize a periodic wave of frequency f with the harmonics (sine waves) with frequencies f, 2f, 3f, and so on. These are called partials.

Fourier series is like c o o k i n g food, where the harmonics serve as all the i n g r e d i e n t s you ever need. You need the right r e c i p e. We will do this for the square wave.

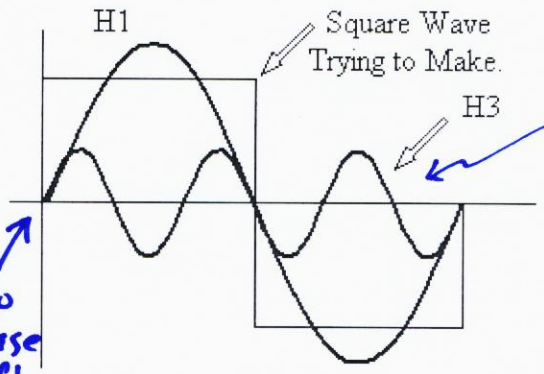
One decides on each harmonic's amplitude and Phase.

How much of each

You might have to shift a harmonic for the best results.

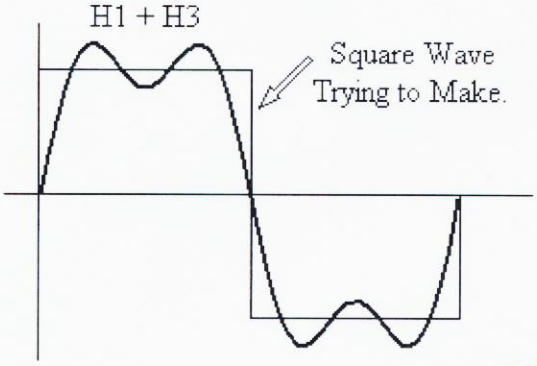


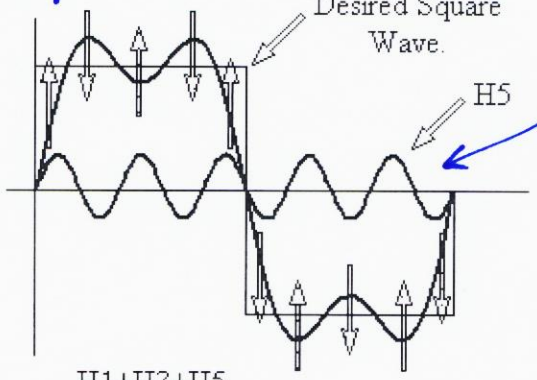
First sine wave used (H1).



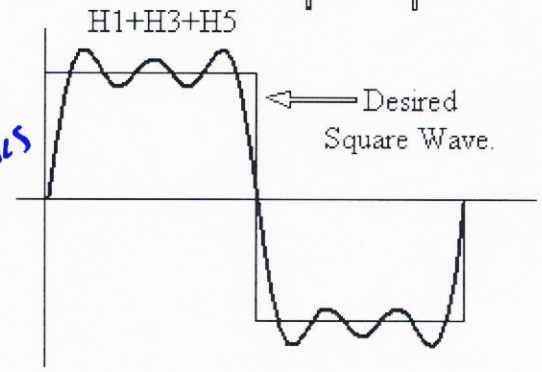
No phase shift necessary.

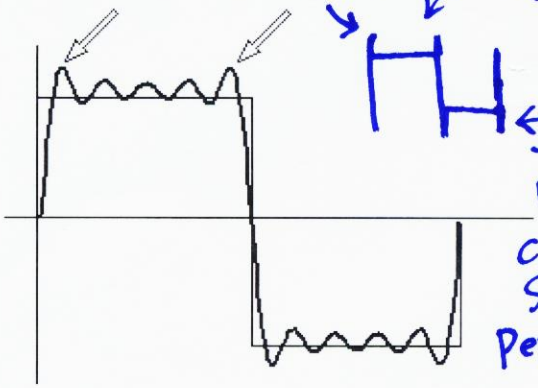
Best amount is 1/3 compared to H1 which we take to be "1" full cup.





Best amplitude is 1/5.

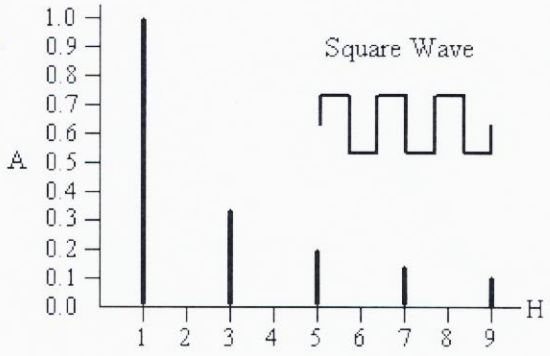




as you add "zillions" of harmonics ← still there but close shut. Perfect acoustic match.

First 9 Fourier Amplitudes for Each Waveform.

	H1	H2	H3	H4	H5	H6	H7	H8	H9
Sine	1	0	0	0	0	0	0	0	0
Triangle	1	0	1/9	0	1/25	0	1/49	0	1/81
Square	1	0	1/3	0	1/5	0	1/7	0	1/9
Ramp	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
Pulse Train	1	1	1	1	1	1	1	1	1



Above is a bar graph of the first 9 Fourier amplitudes for the square wave.

Brahms: *First Piano Concerto* (1858). Progression: 1 - 4 - 1 - 5 - 1. Brahms: *First Hungarian Dance.*