The Fourier Series
Fourier Analysis

Female:
We're stuck, but I have an idea! We'll play it over our phones! Can you do it?

Male:
Yeah.

Commentary:
Nice idea, but what's the reality?

[Music plays down phone]

Music and voices sound so tinny down the phone. And Fourier series can explain why. We went to the British Telecom research facility near Ipswich to investigate.

Phil Sheppard, British Telecom:
The voice sounds different on the telephone mainly because we're trying to transmit the speech down a limited bandwidth channel so we try to compress the speech effectively into that channel by cutting off the high frequencies and cutting off the low frequencies, and that gives us the remaining bandwidth that we have for speech and telephony which is 300 hertz to 3.4 kilohertz.

Commentary:
And with the frequency range reduced, the colouring provided by the higher harmonics just vanishes, but for speech that's not an enormous disadvantage.

Phil Sheppard, British Telecom:
You can actually top up some of the speech and still get quite an intelligible sound of speech, so you can chop off some of the higher frequency and though you lose some of the fidelity of it you can actually understand intelligibility, and you can cut off some of the low frequency and although you lose some of the naturalness, it sounds a little bit higher pitched, you can still sound quite intelligible.

Commentary:
This computer model demonstrates the effect of limiting these frequencies. At the top of the screen is a graphical representation of two speakers. First, top left is a male voice.

Male voice:
The wind slammed the door.

Commentary:
Then on the right, the female voice.

Female voice:
You were the perfect hostess.

Commentary:
The voices represented in the middle have had the lower frequencies removed. On the left the male voice…

Male voice:
The wind slammed the door.

Commentary:
…is notably changed. But the female voice…

Female voice:
You were the perfect hostess.

Commentary:
…changes less because it has fewer lower frequencies. At the bottom of the screen are the same voices with the higher frequencies removed, just as we would hear them on the 'phone.

Male voice:
The wind slammed the door.

Female voice:
You were the perfect hostess.
Commentary:
Both voices have changed noticeably.
Male voice:
The wind slammed the door. The wind slammed the door. The wind slammed the door.
Female voice:
You were the perfect hostess. You were the perfect hostess. You were the perfect hostess.
Commentary:
But why alter the voice at all?
Phil Sheppard, British Telecom:
We need to reduce the bandwidth so we can transmit the speech, so that we can reduce the cost of the telephony call, and by squashing the speech especially into this limited bandwidth we can send many more telephone calls down the same line, and therefore reduce the cost.
Commentary:
To achieve these cost-cutting benefits it's important to understand the voice, and that requires Fourier analysis.
Phil Sheppard, British Telecom:
We use Fourier analysis in a number of ways to analyse the speech that we're sending on the network, and the speech that is being received at the other end of the network, and we can then use those to compare what the network has actually done to the speech and what degradation it's put into it.
Commentary:
Understanding the behaviour of the waveforms allows amplification and the improvement of signals so that the quality is maintained throughout the network. With a mobile 'phone the problem's the same, but worse.
Phil Sheppard, British Telecom:
Well mobile 'phones are basically trying to get the same amount of frequency bandwidth into the transmission, but because they've got a lot less bandwidth to play with in their transmission reading, they're using a radio signal with limited spectrum to play with, they actually have to code it up digitally into a much lower bandwidth signal.
Commentary:
Using a mobile 'phone is probably not the best idea here. They compress the sound even more than landlines. For music this can be disastrous. Even a simple note would lose a lot of the texture given by the higher harmonics, the important timbre. A violin and a flute could end up sounding the same.