



## The Fourier Series

*Stocking the supermarket*

### Commentary:

Now, we promised you a look at how Fourier series can help with stocking supermarket shelves. Fourier analysis has an obvious role in the analysis of sound, but its use in the retail trade is far less obvious. Warehouse space costs money so companies want to buy in goods for as short a time as possible. To do that they need accurate forecasts of how and when customers buy their goods. The Institute of Operations Management stage conferences to discuss these issues, and Barrie Webster is one of the contributors.

### Barrie Webster:

One of my fundamental beliefs is that there is only one customer in a supply chain and that is the consumer. There are no other customers. The Institute of Operations Management is an organisation that's been around for a long time. It's a professional body that it tends to introduce and extend the concepts, the philosophies originally behind production systems and inventory control systems, but they've changed their name recently because it's now much broader, it now incorporates a lot of logistics functions, supply chain planning functions, and is a very successful organisation with a substantial number of members.

### Commentary:

It's the seasonal nature of goods that has suggested using Fourier analysis. We know that tinsel sells well at Christmas and barbeques in the summer, but other goods tend to vary on a monthly basis, and that is why demand planning is used.

### Barrie Webster:

Demand planning covers a number of different features but the starting point is forecasting, and the issue that we deal with is companies who have to predict what consumer demand is going to be, and the basic problem they have is that they have customers who come along and want their products, and want their products either immediately or in very, very short times. The difficulty is that it can take a long time to produce the product, and can often take a long time to get through the distribution chain. Therefore what they need to do is they need to generate projections of what the consumer demand is going to be in advance of it actually happening.

### Barrie Webster:

It really is a whole new generation of statistics...

### Commentary:

The basis of any statistical projection is the data that's been collected, so Barrie uses sales data in his software to predict future demand.

### Barrie Webster:

That line there is now so if I go that way I'm going into the past, if I go that way I'm off into the future. I'm showing three years historically there and I'm showing two years in the future. That red line represents the actual demand for that particular product over the last three years. Now this particular one I'm showing you is real data, it's actually canned lager, it's a major brand of UK lager, it's the number of tins that are sold per month so the volume is actually, is actually quite substantial. When you plot it you can actually see the pattern of demand, and what the statistics allow us to do is it allows us to detect first of all this level here.

### Barrie Webster:

The statistical forecast that we developed consists of three main components. The first of one is what we call a level which is the underlying demand in terms of how many you sell per period – the period could be a day, a month, a week, and you may sell ten, a hundred, a thousand, or whatever. The second component is what we call the trend which is the rate at which sales are growing or the rate at which sales are declining. And the third element is the seasonality component and that's very much where Fourier issues comes into play. We use Fourier series to automatically detect whether there is first of all any seasonality at all within a demand pattern, and if there is seasonality we detect how many harmonics, i.e. how many peaks and troughs you actually have in the time series itself.

**Commentary:**

The amplitude of peaks and troughs reflects sales in each period and seasonality appears in a vast number of products. Christmas cards and Easter eggs are obvious, but soft drinks tend to sell faster in hot weather.

**Barrie Webster:**

Things like lager, for example, tend to have a peak at Christmas but also have a peak in the summer in the warm weather, so you'll find that different products can have a different number of peaks and troughs throughout the year, and Fourier series are ideal in actually measuring that seasonality profile.

**Commentary:**

Creating waveforms that mimic this trend uses Fourier. Look at Barrie's plot of demand. We have what looks like a waveform. The role of the first harmonic is played by the annual variation in sales. Barrie has suggested a second harmonic, a twice yearly peak in lager sales – but are there any others? We could guess at some. Monthly paid people might spend more on pay day, a higher frequency seasonality, in fact the twelfth harmonic; likewise the 52nd harmonic, the weekly shopping excursion. The contribution of these harmonics varies with the product. Estimating these contributions from data and creating software to predict future sales will maximise profit, so that's how Fourier series can help forecast stock levels, but it has limitations.

**Barrie Webster:**

Once you've gone down to weekly data, or certainly down to daily data, then Fourier series doesn't tend to work too well. The patterns are really distorted by the amount of noise in the data, and at that particular stage you're much better off using other techniques other than Fourier series in order to model the effects.

**Commentary:**

Fourier analysis looks at the combination of simple waveforms to make more complex ones. It also facilitates maximum transmission rates for 'phone users. It's possible your local food store relies on demand planning so whether you're writing that musical masterpiece, 'phoning home or shopping, Fourier series are at hand.