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Resonant Networks

We take resonance for granted but it is the building block of every modern telecommunications network. Resonant networks are efficient networks. You might think that we know all we need to know about resonance but it turns out we are still discovering resonant effects which have profound relevance to our ability to communicate.

In last month's technology topic, Smart Quantum from Space, we studied the science of the very small, the application of which turns out to be dependent on our limited understanding of the resonant behaviour of sub atomic particles.

This month we turn our attention to the very large and the study of resonance at a cosmological scale including areas of research which have a direct bearing on future radio and optical terrestrial and space communication.

As radio engineers, our understanding of resonance tends to start at long wave and stops some way short of light. Over the past thirty years this has included an increasing focus on millimetre band radio from 30 GHz to 300 GHz (10 millimetre to one millimetre wavelength).

As optical engineers, our understanding of resonance tends to start at long wave infra-red (300 GHz to 3000 GHz, medium wave infra-red (3 THz to 30 THz) and short wave infra-red (30-300 THz)

The short wave infra-red band is sub divided into O band, the 'Original' band at 178-184 THz (1675 to 1625 nm), L band, the 'long' short wave band from 184 to 191 THz (1625 to 1565 nm), C band, the 'conventional' band from 191 to 195 THz (1565 to 1530 nm), S band, the 'short' band from 195 to 205 THz (1530 to 1460 nm), E band originally an 'extension' of O band from 205-220 THz (1460-1360 nm), O band, the 'original' band from 220 to 237 THz (1360 to 1260 nm). The controllers we use to turn our TV's on and off are at 318 THz (940 nm). This near visible band is also used for Vertical Cavity Surface Emission Lasers (VCSEL). Laser devices in the near visible band are power limited to prevent eye damage.

Most transmission systems used the low loss windows at C band and O band for longer distance links. Any of these systems could use simple intensity modulation as used for example in building and local area Li-Fi but like early spark transmission radio these are relatively broadband systems (8 or 16 THz optical channel spacing)

The vast majority of longer distance optical communication systems use coherent modulation at 25 GHz channel spacing. In principle these system could then scale through visible light from 460 to 750 THz though eye damage risk becomes problematic and then on through the ultra violet bands (A, B and C from 750 THz to 3000 THz). We are then into ionising radiation which is potentially an excellent communications medium apart from its ability to kill us.

We can of course set off in the other direction and go down in frequency from Long Wave. This includes wavelengths that are hard to measure due to their frequency or rather infrequency. As an example, research is ongoing to discover why the intergalactic clouds of hydrogen and helium are hotter than they should be.

One theory is that they are being warmed by sound waves at a frequency of one cycle per ten million years equivalent to a B flat fifty four octaves below Middle C. It is nice to think that we live in

a universe that is tuned to the B flat trumpet. In parallel, Voyager 1, now almost 45 years old and 14 billion miles from earth has yielded measurements of a persistent steady 3 KHz hum from the plasma in near inter stellar space.

Our present understanding of resonance is largely due to the work of Pythagoras in the sixth century BC. His mathematical triangle of ten dots with four dots on the bottom row, known as the tetractys can be used to describe all of the intervals used in modern music including the octave, the perfect fourth and fifth and the associated diatonic scale structure. Radio and optical engineers use similar mathematical principles to work out wanted and unwanted mixing of radio and optical frequencies.

The same theory is being applied to string theory and the related effort to find a unifying theory that embraces Newton, Maxwell and Einstein.

String theory is based on a modelling of sub atomic particles which treats the particles as a string like entity (rather than a point source) with a resonance that corresponds to a certain mass and charge. The string can be terminated at one end or both ends. As with a musical instrument, a resonance in one string will induce a resonance in an adjacent string.

This might help to explain phenomena such as entanglement and could be a way of unifying all four nature's known forces, gravity, electro magnetism and the strong and weak nuclear force and to explain why the universe continues to expand at an ever increasing rate. The assumption is that this has something to do with all that dark energy pouring out of the event horizons of black holes and the dark matter hidden in the holes including the ratio of dark energy (68.3% of the Universe) and dark matter (26.8% of the Universe). After all this time it might not be gravity that is keeping our feet on the ground but dark energy- we are being pushed rather than pulled to the ground. String theory is not universally accepted but does sensibly build on the principle that the very small potentially scales to the cosmologically large.

In 1910, inspired by the work of Marie and Paul Curie, Ernest Rutherford placed a piece of radium in a lead lined box with two holes drilled in the side and discovered that the light from the holes passed straight through a thin sheet of gold providing observable proof that the atom was divisible (atom means indivisible in Greek). The interference effect of the gold sheet enabled Rutherford to calculate that the nucleus of the atom was one hundred thousand times smaller than the atom itself and was surrounded by orbiting electrons but also that the nucleus was a sphere within which even smaller particles could be circling around which themselves could be spheres containing possibly smaller spheres with everything spinning to the left or the right or in all directions at once.

At this point it is worth bringing Mr Benoit Mandelbrot into the debate. Mandelbrot is best known for his work on fractal geometry but also worked on the related science of self-similarity, the replication of physical shapes and structures over many orders of scale. Mandelbrot also pointed out the unlikely relationship of resolution and distance in which a coastline becomes longer depending on the resolution used to measure it.

It can be generally stated that our failure to understand small and big things is due to our inability to view the very small and very big or at least our inability to view the very small and the very big with sufficient resolution. Just because we cannot see something does not mean it isn't there. So for example, we assume that quantum physics is significantly different from classical physics because we have observed probabilistic behaviour that does not occur in the classical domain That of course might be because we are viewing either or both domains at the wrong resolution and or from an incompatible time base, in effect the same problem that we have with measuring that acoustic wave that comes around every ten million years. Imagine your frustration if you missed it.

And it could be that the atom including the quantum behaviour of sub atomic particles in the nucleus of the atom is actually a perfect scale model of the Universe.

Pythagoras considered the earth as a sphere with the heavens as a celestial sphere of arcs and circles with the earth at its centre. Plato took the idea of spheres within spheres and added resonant qualities – the singing universe. For the lack of a better description let us call this the Sphere Theory of the Universe.

In 1929 Hubble observed that some galaxies were red shifted which meant they were moving away from us and some were blue shifted which meant that they were moving towards us. He also observed that the number of red shifted galaxies exceeded the number of blue shifted galaxies proving that the Universe was getting larger. This meant and means that the resonant frequency of the universe is reducing over time, the soprano universe becomes the alto universe becomes the tenor universe becomes the basso profondo universe.

This might of course be nonsense but the idea that the Universe is made up of spheres which spin and sing is not that distant from string theory.

As Lorenzo says to Jessica in the final act of William Shakespeare's Merchant of Venice,
There's not the smallest orb which though behold'st
But in his motion like an angel sings
Such harmony is in immortal souls
But whilst this muddy vesture of decay
Doth grossly close it in, we cannot hear it'.

You might ask what on earth does this have to do with telecommunication networks and the answer is nothing because we are not talking about networks on earth but networks in space with each constellation having its own assigned radio and optical frequencies supporting satellites with their own assigned radio and optical frequencies communicating with devices on earth that are frequency resonant with the satellites flying overhead.

Like Lorenzo, we cannot hear the satellites sing but we can celebrate the celestial campanology behind these modern choirs in the sky, the ring tones of our near space Universe.

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00 44 7710 020 040