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Deep Space, Near Space, Our Space

On the eve of the World Radio Conference, we felt it would be useful to have a look at the evolution of space radio over the past sixty years and more specifically to review the progress of Voyager 1 and 2, two of the oldest still operational space craft and what this tells us about the changing economics of space based connectivity.

Just over a year ago a sudden dip in detected charged particles from the sun marked the transition of Voyager 2 from the edge of the solar system into inter stellar space.

The telemetry data had been transmitted on the 20 watt S band transmitter via a 3.7 metre antenna and received 16 hours later by the three NASA 70 metre Deep Space Network Telescopes spaced equidistantly 120 degrees apart in California, Spain (Madrid) and Australia.

Voyager 1 had made the same transition six years earlier. Both spacecraft report back several times a week and have enough radio isotope power to stay in contact for another eight years by which time the spacecraft, their radio systems and their radiation hardened silicon on sapphire microcontrollers will be fifty years old.

Voyager 2 is presently some 18 billion km (11 billion miles or 116 astronomical units) from Earth. Voyager 1 is 22 billion kilometres away.

Thanks to some clever sling shot maths passing Jupiter and Saturn (and Uranus and Neptune for Voyager 2) the two craft are travelling at over 54,000 kilometres per hour (34,000 Miles per hour) and are the fastest man-made objects ever built. The progress of the two space craft is tracked on the NASA Voyager web site.

https://voyager.jpl.nasa.gov/mission/status/

They will arrive at the Oort Clouds in 300 years' time and emerge the other side of the Oort clouds in 30,000 years' time. 10,000 years later, **Voyager 1** will drift within 1.6 light-years (9.3 trillion miles) of AC+79 3888, a star in the constellation of Camelopardalis heading toward the constellation Ophiuchus. Both craft will then potentially remain in orbit around the centre of our galaxy for billions of years.

If alien life forms ever get to take either craft apart, they will have a snapshot of state of the art radio communication on earth in the 1970's.

Space radio has followed a similar trajectory to all other radio systems.

In 1957 Sputnik 1 used a radio beacon transmitting at 20.005 MHz which could be tracked by ground based short wave receivers, including the recently completed Lovell telescope at Jodrell Bank in the UK.

The assumption, never proved or disproved was that the duration of the beeps carried information about conditions on the satellite and for Sputnik 2 information about the health of Laika, the first dog in space (not a happy ending for the dog).

The beacon was also be used to obtain information about the Earth's upper atmosphere including the ionosphere.

The early US satellites carried beacons that transmitted on 108 MHz and then 136 MHz which became known as 'the space band' and then 378 MHz.

In the 1960's NASA spacecraft started using S band then X band.(Voyager 1 and 2 have S band and X band transceivers with Ka band added in from the turn of the century.

Unified S band (2.025 to 2.3 GHz) was used for the Apollo lunar missions. This was based on a Universal Serial Bus standard established in 1965 supporting simultaneous voice, telemetry and television which is how we received the iconic footage from the Apollo 11 mission fifty years ago.

The standard implemented slow scan TV modulated on to the carrier with telemetry data phase modulated on to the sub carriers. The standard also supported accurate ranging.

From the early 90's onwards, the Deep Space Network has been supplemented by the Near Earth Network, a development from the Spacecraft Tracking and Data Acquisition Network (STADAN) established in 1961, also originally known as the Ground Network.

These are smaller dishes than the DSN (typically 10 or 12 metres) but there are more of them and they are more widely distributed (Singapore, Malaysia, Antarctica, the US, New Mexico, South Africa, Sweden, Chile, Alaska, Australia and Hawaii) and provide telemetry and telecommand, tracking data and communications for satellites in low earth orbit, medium earth orbit, geosynchronous orbit, highly elliptical orbits and lunar orbits.

The advent of high count LEO constellations requires a massive increase in the number of dishes looking up at the sky. The FCC filings from Amazon for Project Kuiper cite the need for 'millions of earth stations' though this includes earth stations in motion (ESIMS) and compact flat panel and conformal arrays mimicking the function of dishes but with additional pointing flexibility.

This has created tension between existing satellite operators and the NEW SATS with the potential desensitisation of earth ground stations from new LEO satellites looking directly downwards being a contemporary concern.

New market entrants argue that it is simple to switch off transmissions when directly overhead or achieve sufficiently high protection ratios from angular separation. Similar coexistence considerations apply to downward looking MEO satellites flying through earth station to GSO sight paths.

However if angular separation is generally accepted as an effective and efficient way of providing adequate protection ratios in shared satellite spectrum then it automatically follows that terrestrial and satellite can also co share particularly given present improvements being achieved in beam forming and the active nulling of unwanted signal energy.

This opens up opportunities for satellites to provide service access in 3GPP FR1 and FR2 bands and vice versa for terrestrial to provide services in existing satellite bands. Where spectrum allocations are immediately adjacent, there are useful opportunities to widen existing pass bands, for example by combining existing satellite spectrum with present Band 1 allocations. Conversely the FR2 N258 band overlap with near earth network K band spectrum presents potentially interesting technical and commercial opportunities.

For 5G, this implies significant potential gains in spectral efficiency and geographic coverage. For satellite operators, the benefits include scale and increased income from existing and future space assets.

In an after dinner speech earlier this year Buzz Aldrin talked about the lack of progress in the fifty years since the moon landing in July 1969.

While this is true when applied to manned space exploration it does not apply to radio systems. Terrestrial radio systems have gone through fifty years of technical and commercial transformation and changed the world in which we live.

Space radio systems have in parallel proved that radio technology can still work immaculately after decades of use in the most extreme conditions. Innovations such as the microcontrollers used in those Voyager spacecraft were crucial to the realisation of first generation cellular radio. Space research on materials and manufacturing process remains essential for earth based radio and computer hardware innovation and useful consumer products such as………Teflon.

The disciplines of space engineering can also yield significant economic benefits in terms of resilience and extended life cycles. The first generation of Iridium satellites were expected to last seven years but in practice delivered an operational life of nearly twenty years. Traditionally the amount of on board hydrazine has limited the time in orbit but the present generation of electric satellites with solar powered ion thrusters could deliver satellites that could stay in low and medium earth orbit for thirty years or more. Coupling on orbit longevity with radio systems that work over similar time scales creates the opportunity to deliver a whole new generation of cost effective space based connectivity.

It would be a pity if disputes over spectrum frustrate this potentially mutually beneficial cooperative process.

5G and Satellite Spectrum, Standards and Scale

Our latest book, **5G and Satellite Spectrum, Standards and Scale** is available from Artech House. You can order a copy on line using the code VAR25 to give you a 25% discount.

http://uk.artechhouse.com/5G-and-Satellite-Spectrum-Standards-and-Scale-P1935.aspx

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