RTT TECHNOLOGY TOPIC
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5G Channel Modelling

Our July Technology Topic, 5G Energy, discussed the options for reducing the power consumption of 5G IOT devices but suggested there was a broader need to address network and device power consumption in high data rate wide area high mobility 5G networks.

We referenced White Papers from Nokia and Ericsson highlighting the problem with small cells (consuming three times more power than micro cells) and the fact that energy consumption in the radio access network (accounting for 80% of all mobile network energy use) was currently increasing by 15-35% per year.

The communications industry is not short of spectrum. Satellite operators have access to over 4 GHz of civilian use spectrum aggregated over L band, S band, C band and Ku and Ka band and it must surely be possible to produce a compelling commercial case for at least some of this to be flexibly shared with 5G mobile broadband.

Add in an additional 10 GHz of millimetre band spectrum and it is hard to avoid the conclusion that there is a surplus rather than shortage of spectrum (spectrum as a liability not an asset). There is however a shortage of power.

This suggests that the present focus on making the 5G physical layer more spectrally efficient is misguided. The primary objective should be power efficiency.

From an RF perspective, the starting point for evaluating power efficiency is the link budget and associated channel models which together provide the mechanism for estimating the propagation loss between the base station and the user/IOT device. In the centimetre and millimetre band, the surface roughness of materials will also have a big impact on reflected signal energy.

The link budget includes the power and sensitivity available and required at both ends of the transmit path. Signal to noise calculations also need to be done for inter system and intra system interference taking into account in band and out of band unwanted energy, the periodicity and amplitude of the interfering signals and the selectivity and dynamic range of victim receivers.

Interference between terrestrial and sub space and satellite radio systems also needs to take into account angular power.

Present 5G channel models focus on urban micro cell and urban macro cell and indoor rather than wide area mobile based on the assumption that propagation losses will make larger cell radii impractical and uneconomic.

An alternative approach is to think about 5G as a highly adaptive progressive point to point wide area mobile network. This implies a change in present centimetre and millimetre band modelling methodologies – the subject of this month’s technology topic.

Modelling Methodologies

Contemporary cellular networks are designed using well established propagation models with physical layer RF and baseband parameters determined by a range of user defined pedestrian ‘typically urban’ (TU3), vehicular urban (TU50) and rural channel models (RA250).

These work adequately well up to 2 GHz but become progressively less accurate at higher frequencies/shorter wavelengths.

Discussions around suitable channel models for the centimetre and millimetre bands focus on the relative merits of the *Alpha Beta Gamma* (ABG) model using a floating constant referenced to known and measured data sets, the *Close In* (CI) model referenced against a path distance of one metre and a *CIF* model which adds in a frequency weighted path loss exponent.

The *ABG* model typically under predicts path loss when near to the transmitter and over predicts path loss further way. The CI and CIF models are more accurate and computationally simpler.

Frequencies being studied range from 2 GHz to 73 GHz with a path length of between 4 metres and 1238 metres with models for urban microcells (UMi) with antennas at 10 metres, urban macro cells (Uma) with antennas at 25 metres and Indoor Hot Spots (InH). The CI model works better for outdoors and CIF model for indoors. Both models have a path loss variable that is continuously coupled to the transmitted power over distance.

The measurements and modelling are based on narrow beam 7.8 degree azimuth half power beam width antennas and wideband 49.4 degree antennas.

A need for large cell models?

While this modelling work is undoubtedly useful it excludes larger cell radii on the basis of assumed propagation loss. While this may be a sound assumption for antennas with 7 or 8 degree beam widths and above it is at least worth exploring the viability of larger cells supported by narrower beam width antennas.

Ka band satellite systems for example use fractional beam width antennas with a half power azimuth beam width of between 0.5 and 1.5 degrees. This is partly to offset the additional rain fade margin needed for the Ka band (compared to Ku band) but also to provide coverage flexibility, frequency reuse and interference mitigation. The beam pattern replicates the beam pattern available from a fixed link microwave dish but with the ability to provide dedicated on demand coverage.

Applying a similar approach to terrestrial 5G coverage to individual users and individual devices from dominant high power high towers at least merits study and potentially provides an alternative wide area economic model for delivering high bit rate mobile connectivity. It might also provide a more persuasive technical basis for co sharing satellite spectrum in the centimetre band including repurposing 28 GHz as a dual use band.

As referenced in last month’s technology topic, these studies are making some progress in the US. For example, the AT&T, EchoStar, Hughes Networks and Alta Wireless spectrum sharing framework proposes ways in which fixed service satellite services (FSS) can be integrated with Upper Microwave Flexible Use (UMFU) licenses. Verizon are attempting to establish a similar study framework with Viasat but co-existence and spectral asset considerations continue to frustrate technical and commercial progress.

Interference management and power efficiency

Satellite systems are essentially large macro cell networks supported from high power (up to 15 kilowatt) high platforms (a few hundred kilometres to 35,000 kilometres). They may be supplemented by sub space systems (balloons or drones) at altitudes of 20 to 30 kilometres.

The additional path loss and required rain fade margin for Ka band (27 to 40 GHz) compared to Ku band (12-18 GHz) is offset by the additional gain available from more closely spaced antennas.

Translating this approach to terrestrial networks is not inconceivable. Military radio systems at 70 GHz are capable of supporting 60 kilometre line of sight links so there is no intrinsic technical reason why this cannot be replicated in civilian high power high tower systems anywhere between Ku band and W band (up to 110 GHz).

Signalling load would reduce producing a net gain in power and spectral efficiency and delivery cost per bit could be reduced to the point where wide area rural 5G becomes viable into low ARPU markets.

The terrestrial and satellite coexistence and spectrum sharing studies also imply a need for additional 3D RAN interference modelling which will also need to accommodate Air to Ground (ATG) and terrestrial network co-existence and sub space/terrestrial co-existence.

Summary

Adaptive fractional beam width antennas have a number of advantages.

Adaptive fractional beam width antennas avoid wasting RF energy and deliver over 40 dB of isotropic gain, sufficient to compensate for the additional propagation loss and rain fade margin associated with centimetre band and millimetre band deployment.

Adaptive fractional beam width antennas integrated with advanced dormancy algorithms improve power efficiency and mitigate inter and intra system interference providing a basis for dual use FSS/5G in bands including the 28 GHz band. Reducing intersystem and intra system interference translates into a capacity or coverage or coexistence gain.

Adaptive fractional beam width antennas can replicate the multiplexing gain of MIMO by supporting multiple routing options (including in band repeater and relay links).

Adaptive fractional beam width antennas reduce the need for channel equalisation by reducing delay spread. The channel characteristics will generally be more stable, closer to fixed point to point channel modelling (and guided media). This should allow an additional reduction in channel coding overhead.

Adaptive fractional beam width antennas potentially allow power control to be implemented in the time domain. Power amplifiers can be run at high output power where they can be made intrinsically more efficient.

All of the above require near real time measurement of angle of arrival, angle of departure and angular power. Although this might seem to be an intractable problem, it has already been solved by the automotive industry for 79 GHz automotive radar. The challenge will be whether these techniques can be translated across into devices working in low signal to noise conditions in high dynamic range wide area mobile networks.

The viability of all of these options needs to be tested against a range of new channel models that have yet to be developed or at least have yet to be introduced into the public domain. These additionally will need to accommodate air to ground and ground to air interference modelling.

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00 44 208 744 3163