SPECTRUM EFFICIENCY GAINS RESULTING FROM THE IMPLEMENTATION OF ADAPTIVE TRANSMIT POWER CONTROL IN FIXED TERRESTRIAL LINKS AT 38 GHZ

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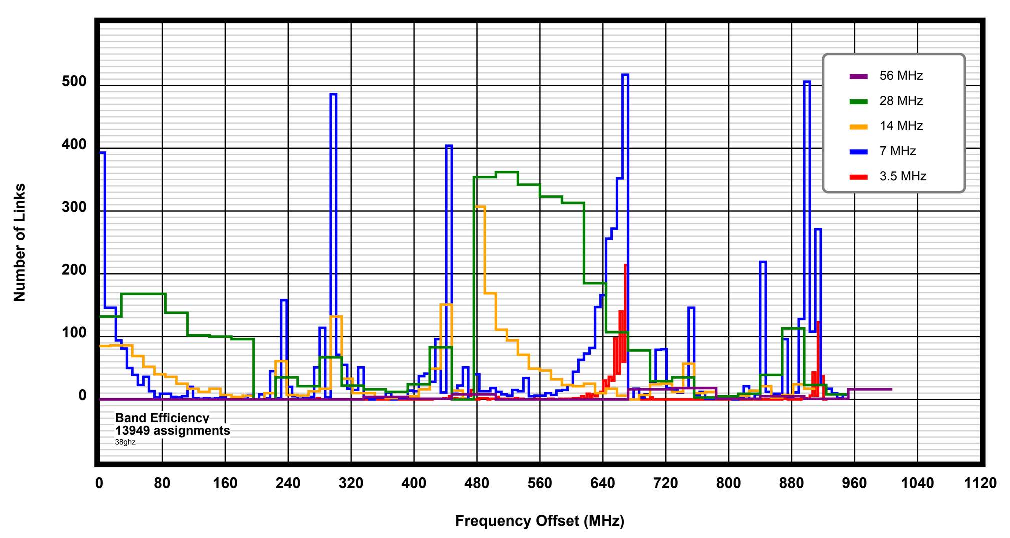
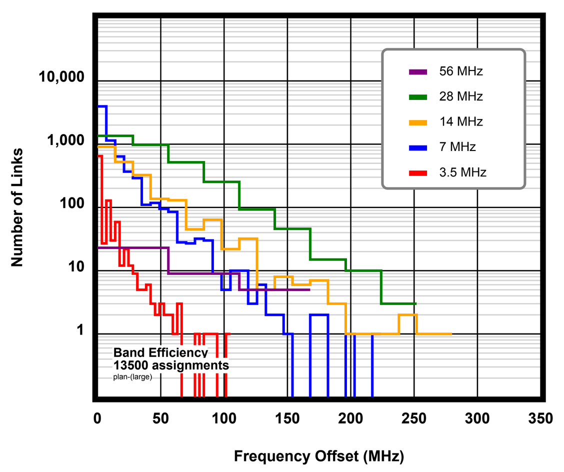
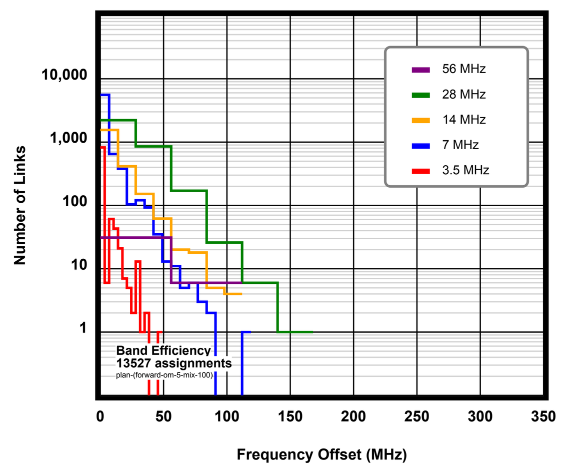
Adaptive transmit power control can be used to improve the spectrum efficiency of terrestrial point to point fixed links by limiting the transmit power to that required to maintain a constant bit error rate (BER) regardless of the propagation conditions. This results in a reduced transmit power being used during clear sky conditions, lowering the interference resulting from the ATPC link. This improves the frequency reuse factor associated with a given band and geographic area, providing a spectrum efficiency gain.



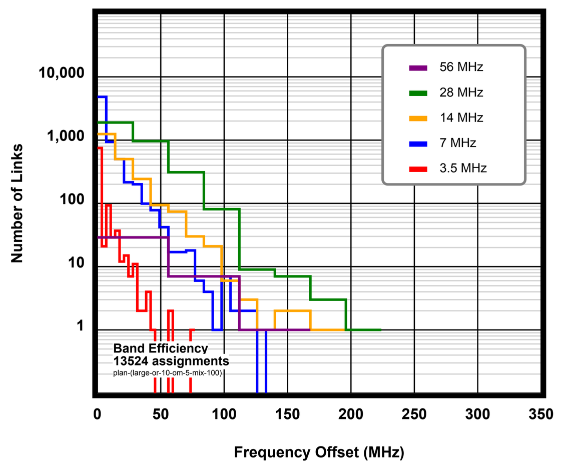
Existing assignments in the 38 GHz band



Automated re-plan (no ATPC) –log scale



Automated re-plan (all ATPC, RFM = 5 dB)—log scale



Automated re-plan (all ATPC, range = 10 dB, RFM = 5 dB)—log scale

Simulation Software

The software written as part of this study has two parts: a planning tool, which plans a set of links using standard planning assumptions, and an analysis tool, which takes a plan produced by the first tool and examines the response of the links to a sequence of rain fields.

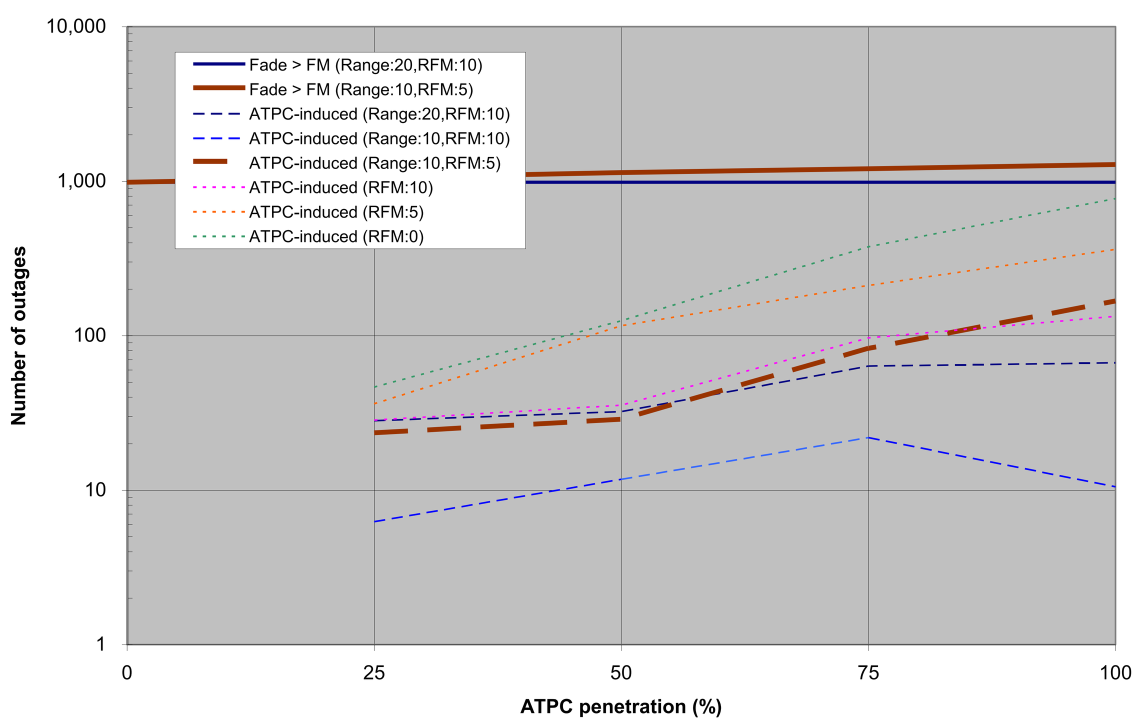
The planning tool takes an existing plan and re-plans it, subject to a number of assumptions:

- the mix of ATPC and non-ATPC links
- the type of ATPC in use.

The statistics of the new plan are then calculated to estimate changes in band efficiency. The initial plan was based on the existing 38 GHz band plan supplied by Ofcom, with 13,949 links. The effect of re-planning the band with the automated planning application results in a contraction of the assignments to the lower end of the band

The analysis tool takes a plan generated by the planning tool (or by another process) and applies a sequence of rain fields, evaluating system performance as measured by outage probabilities. For each rain field, the fade on each link is calculated, which then allows the EIRP uplift to be determined for each ATPC link. Every link is then tested in turn against all interfering paths, for all rain fields, and the number of outages recorded (distinguishing between those outages directly caused by a rain fade and those outages caused by ATPC-enhanced interference); the ATPC-induced outage counts reported here are 'extra' outages (i.e. those outages occurring in a link that is not also in outage because of a rain fade that exceeds its fade margin).

The rainfall rate fields used in this research were obtained by means of the Chilbolton Advanced Meteorological Radar (CAMRa), which is located in Hampshire in the south of England. The radar scans were interpolated onto a square Cartesian grid, with a grid spacing of 300 m and a side length of 56.4 km (188 pixels square). The grids are separated in time by approximately 2 minutes.



The effect of introducing ATPC is shown (left). The number of extra, ATPC-induced outages rises with ATPC penetration, as does the number of outages directly caused by rain, even though ATPC does not, in itself, reduce the protection a link has against rain fading. This rise is caused by the progressive withdrawal of 'excessive' fade margin as non-ATPC links with the 10 dB minimum fade margin are replaced by ATPC links with a lower fade margin (e.g. an RFM of 5 dB); if the remote fade margin is increased to 10 dB, the number of direct outages then remains constant as the ATPC penetration increases.

The results also show the trade-off introduced by assumptions about ATPC equipment capability: a larger ATPC range results in a more efficient plan because EIRPs are minimised; however, if the ATPC range is smaller than typical *FM–RFM* values then some links will have 'excessive' RFM—and will be better protected against interference. Matching the ATPC range and remote fade margin appears to be a very effective method of reducing ATPC-induced outages.

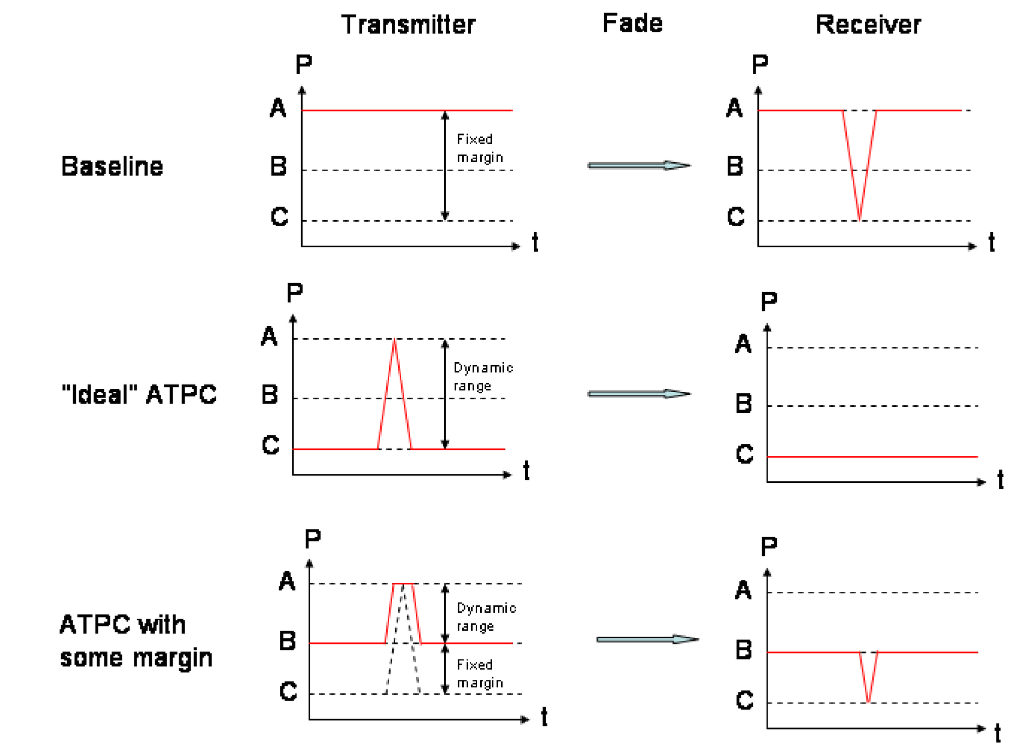
ATPC System Definition

The basic principle for ATPC is quite simple. In cases where rain fading occurs on the radio path, it involves increasing the transmit power to compensate for the fade. Given a reliable power control system, it is possible to reduce the fixed fade margin during clear sky conditions (i.e. no fading), thereby improving the rate of frequency reuse and link packing density in the geographical area of the link. This is because lower fade margins use less transmit power, which lessens the interference on adjacent links.

The operating capability of the transmit terminal is defined by the EIRP levels P_{min} and P_{max} where:

- P_{max} is effectively determined by the maximum EIRP specified by the regulator in order to satisfy a given availability requirement
- P_{min} is determined by the performance of the equipment

$P_{max} – P_{min}$ is the ATPC range.



The "Ideal" ATPC situation cannot be allowed to exist in practice as the received signal level would not give a low enough background block error rate.

The nominal operating condition (i.e. the condition that the ATPC seeks to preserve) is set at a receive signal level a number of dB greater (e.g. 3 to 7 dB) than the 10^{-6} BER sensitivity level. The 3 to 7 dB margin above the RSL is either called the offset or the remote fade margin. The nominal operating condition is set to provide a BER of the order of 10^{-11} or 10^{-12} in order to ensure that the Background Block Error Rate (BBER) is no more than would be the case were ATPC not to be used.

In setting up the link it is necessary to specify P_{max}, in accordance with the maximum EIRP permitted, and to specify the receive signal level associated with the nominal operating condition. When initially setting up the link under nominal propagation conditions the ATPC immediately adjusts the power by way of a transmitter / receiver closed loop to establish the nominal operating condition.

Left - Schematic examples of the power against time for the transmitter and receivers in a non-ATPC system, an ideal ATPC system and an ATPC system with some margin.

Conclusions and Further Work

1. The implementation of ATPC in the 38 GHz band gives significant improvements in spectrum efficiency as measured by the increase in the number of links assigned to channel 1 (from ~50% to ~70%) and the decrease in the maximum bandwidth used (from ~300 MHz to ~180 MHz). The introduction of ATPC does give rise to a number of additional outages in the presence of intense rain (~10% increase in frontal rain). These additional outages can be mitigated to some extent by band-wide changes to the planning process and by matching the ATPC range with the remote fade margin; however, the outages cannot be wholly eliminated by the methods examined here.
2. Adjusting W/U in the planning process is a more effective technique for reducing ATPC-induced outages than adjusting the fade margins or interference margin. However, it is evident that none of these band-wide mitigation techniques targets the ATPC-induced outages very effectively.
3. Based on the similarity of average fade margins between the 38 GHz band and other high frequency fixed link bands, gains in spectrum efficiency should equally be possible in those other bands.

Further work is being carried out on the effects of combining ATPC with soft boundary frequency assignment and adaptive coding and modulation.

The final report of this project is available on-line at

http://www.ofcom.org.uk/research/technology/overview/ese/atpc/atpcfinal2.pdf

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