Implementing Adaptive Transmit Power Control in Fixed Terrestrial Links: Spectrum Management and Interference Issues

Sarah Callaghan,
STFC – Rutherford Appleton Laboratory
Chilton, Didcot, OX11 0QX, United Kingdom
Email: s.a.callaghan@rl.ac.uk
Telephone: +44 1235 445770
Fax: +44 1235 446140

I Inglis , P Hansell
Aegis Systems Ltd,
Cobham, Surrey KT11 2LA,
United Kingdom

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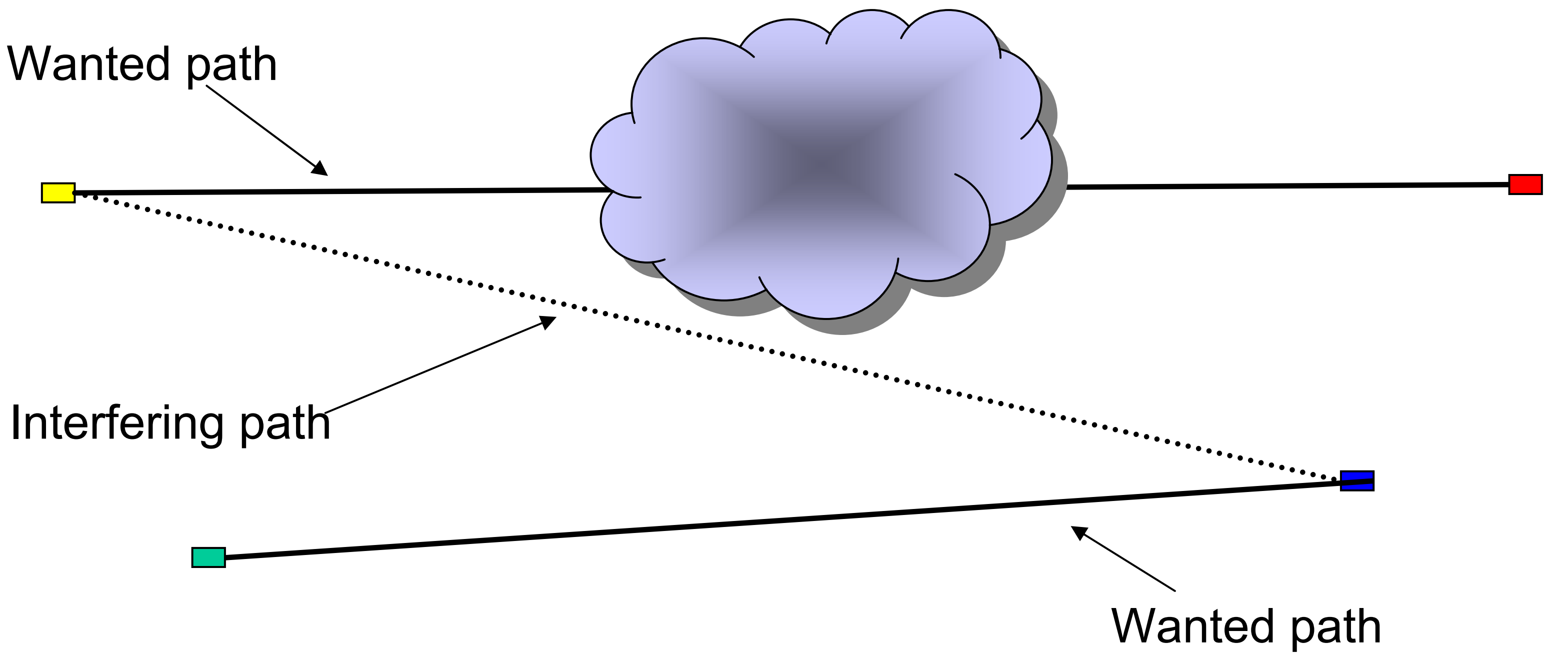
Fixed terrestrial link network using ATPC

Adaptive Transmit Power Control involves turning the transmit power up on a dB by dB basis to compensate for rain fading. This also increases the transmit power on the sidelobes and unwanted paths, increasing interference into neighbouring links.

Best case is when the rain field is correlated (widespread rain) as interfering path will then be as attenuated as much as the wanted path, so turning up the power will produce no real change in interference.



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Application of ATPC in congested spectrum

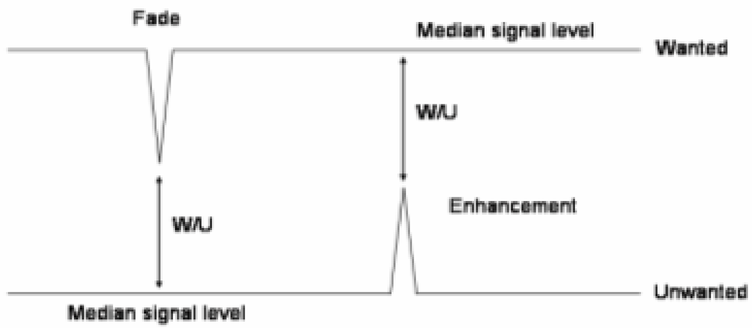
The assignment criteria used by Ofcom to determine whether a new frequency assignment can be made to a point-to-point link without receiving or generating unacceptable interference address two different situations:

1. The wanted path is in its faded state (i.e. at the Receiver Sensitivity Level, RSL) and the interfering path is in a state that gives rise to its median received signal level, as modelled using ITU-R Recommendation 452.

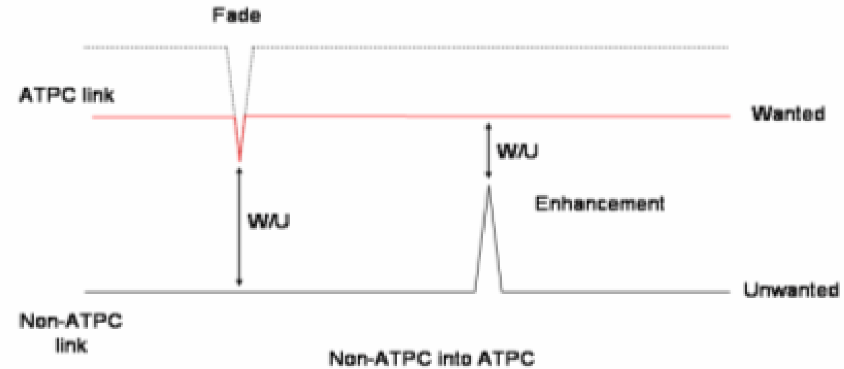
2. The wanted path is in an unfaded state, as represented by the median received signal level, and the interfering path is enhanced, once again as modelled using ITU-R Recommendation 452.

In both of these situations it is necessary to satisfy a given wanted to unwanted signal ratio (W/U).

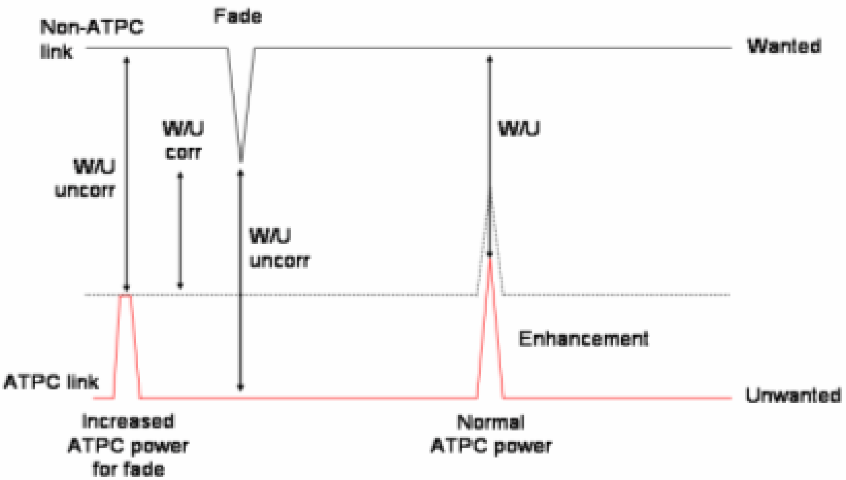
Schematic examples of W/U



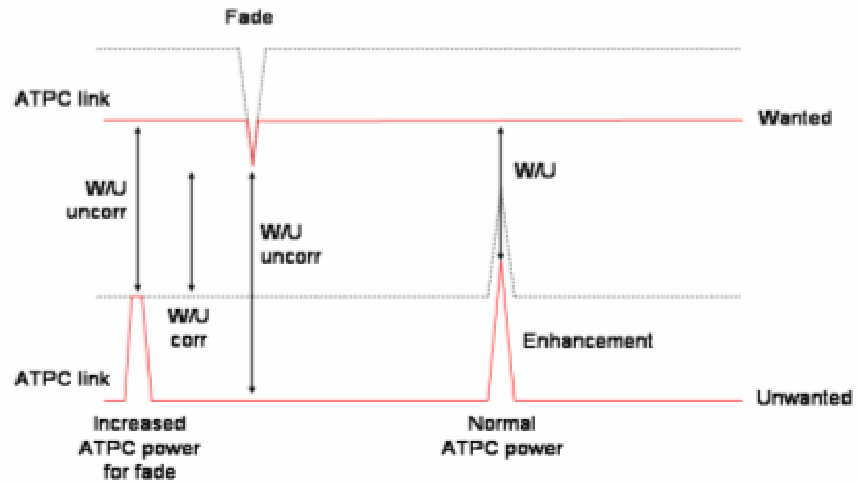
Baseline : Non-ATPC into non-ATPC



Non-ATPC into ATPC

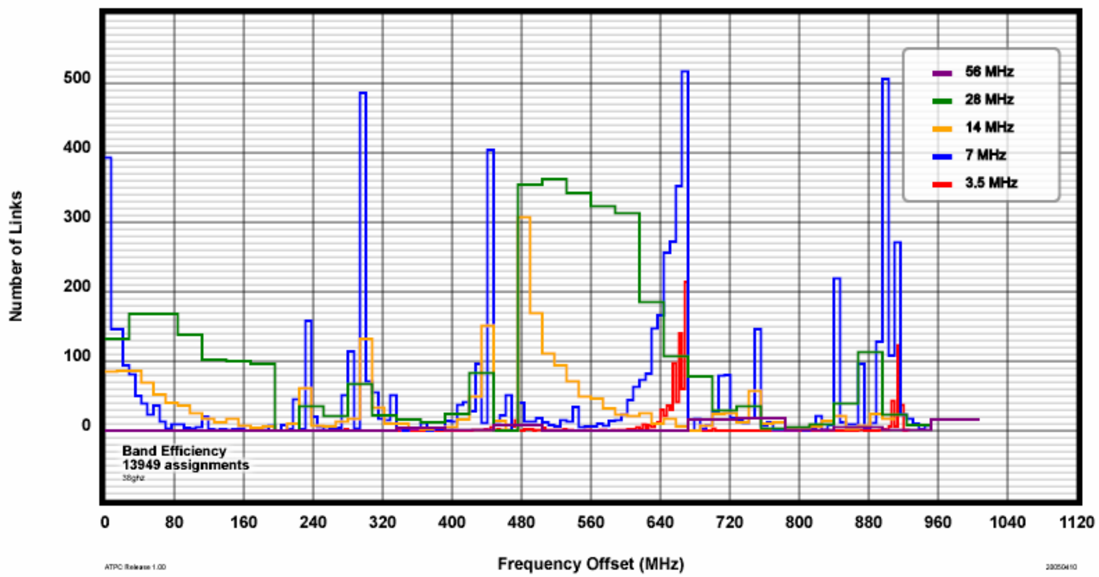


ATPC into non-ATPC



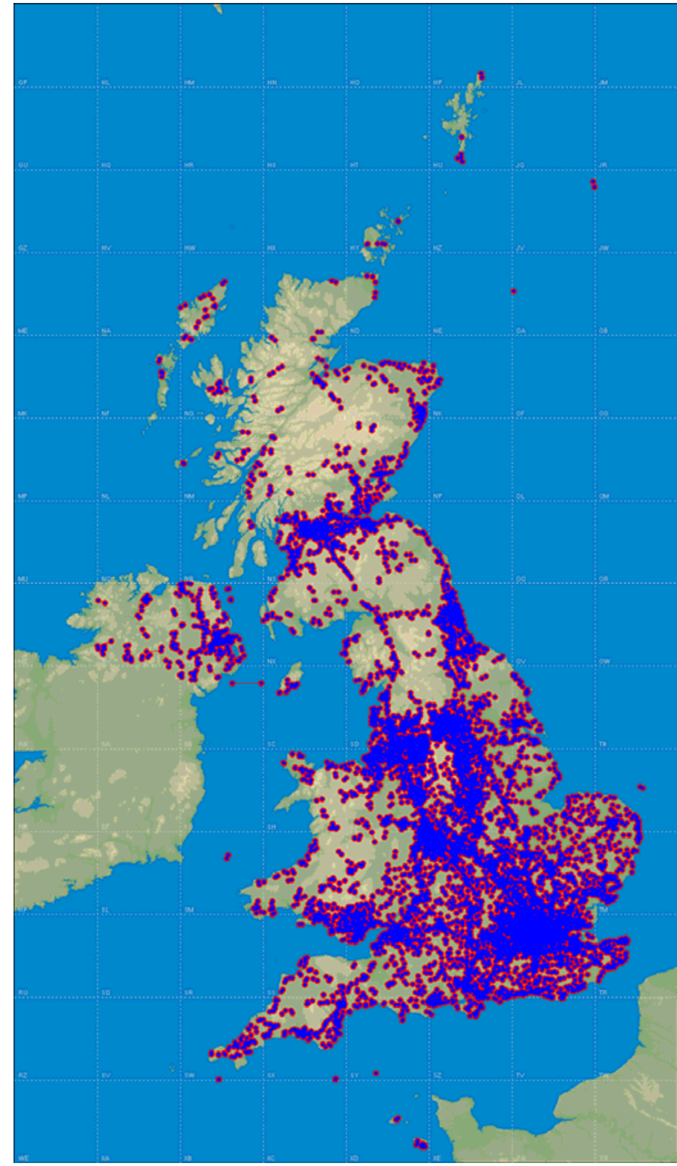
ATPC into ATPC

The effects of implementing ATPC in the 38 GHz band



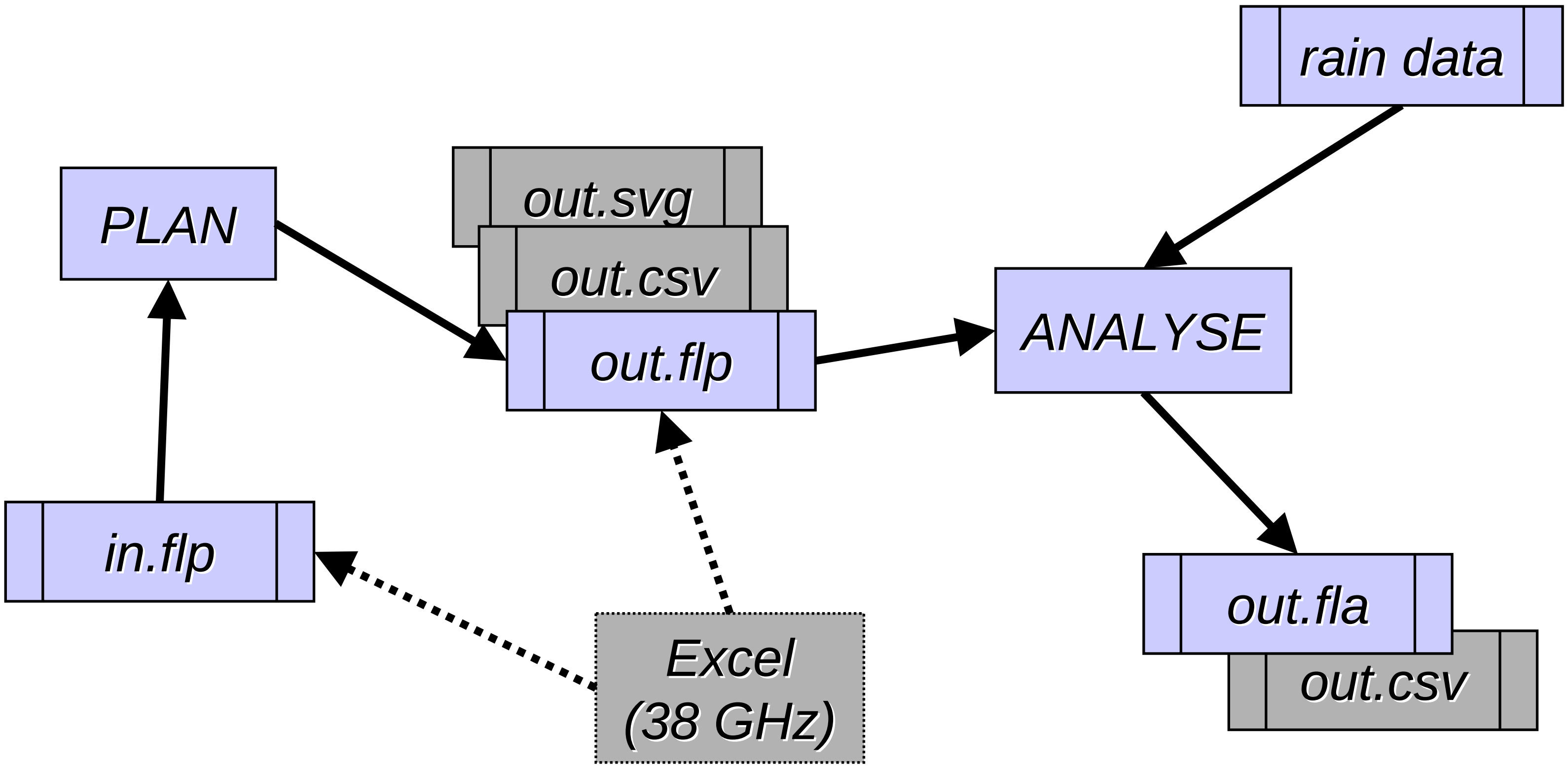
Link allocations in the 38 GHz band in the UK. Total: 13,949 links

ATPC can give a spectrum efficiency benefit. Instead of having a fixed fade margin, if fading is compensated for on a dB by dB basis, then the links can be packed closer together in a given geographical area.

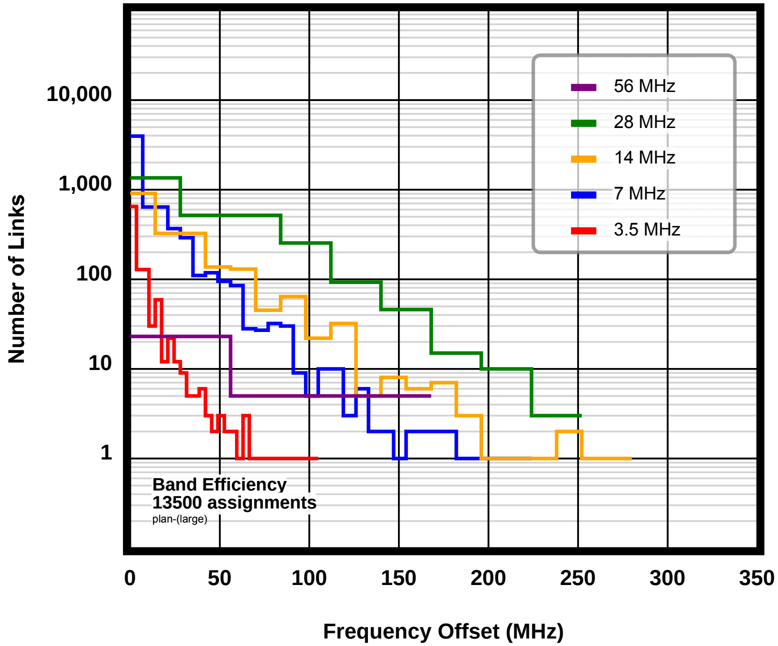


Impact of ATPC

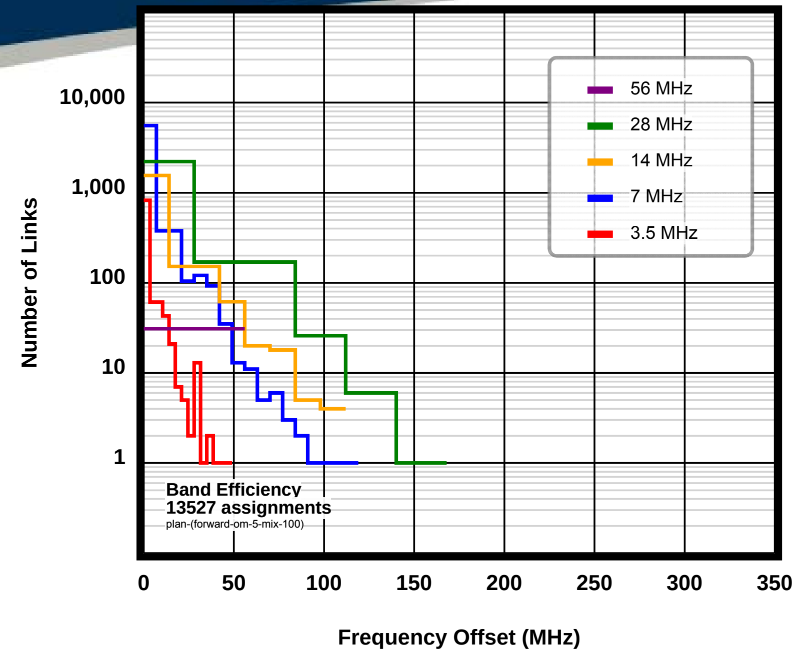
During rain events, does the use of ATPC increase harmful interference to neighbouring point-to-point systems, exceeding the frequency assignment criteria? And if so, how often and how badly will the criteria be exceeded?



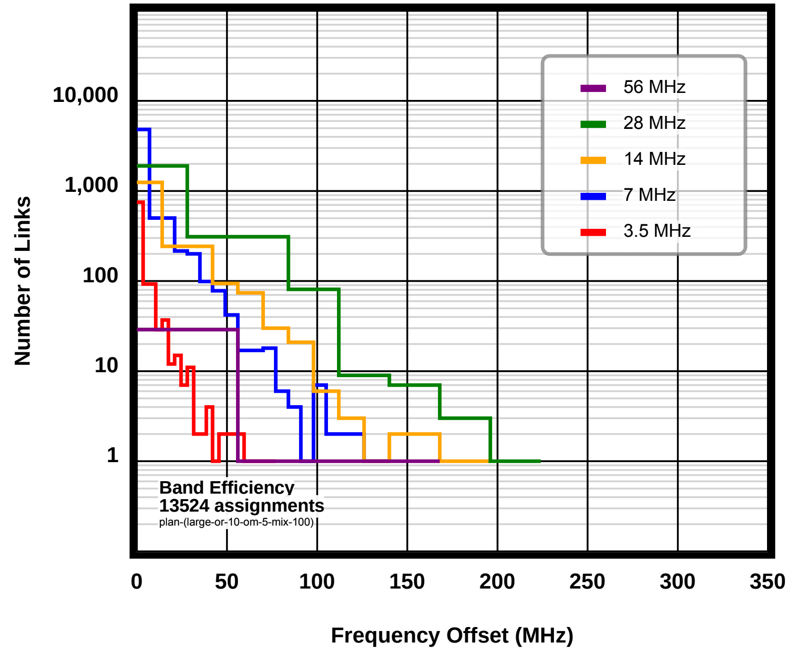
Re-planning the band



Non-ATPC



All ATPC, RFM =5dB



All ATPC, Range = 10dB RFM =5dB

ATPC in the presence of rain

The analysis tool takes a plan generated by the planning tool 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 is recorded

We distinguish between outages directly caused by a rain fade and those outages caused by ATPC-enhanced interference. The ATPC-induced outage counts are ‘extra’ outages.

Rain data used

CAMRa

Combination of measured rain data from CAMRa and simulated rain data from a fractal model.

To avoid edge effects, the analysis was performed on a smaller ‘test’ area. Interference was considered from links throughout the entire area (the ‘background’).

Simulations using the measured data were run using a square 35 km test area set in the centre of the 56.4 km background area. The pixel size for the measured data was 300m.

Simulations were run with a test area of 35 km (background 56.4 km) and 50 km (background 70 km). The pixel size for the simulated rain data was 100 m

Rain effects

The number of detected outages depends upon the severity and distribution of the rain.

The rain will directly cause an outage in a link if the fade exceeds the link's fade margin (whether or not the link uses ATPC)—in other words, when the 'signal excess' (*fade–FM*) exceeds 0 dB.

Extra outages occur as a result of ATPC-induced interference and are counted if the wanted link is not already out as a result of rain fading.

The measured frontal event used here is an extremely rare event. On average, a rain rate of 25 mm/hour is exceeded for 0.01% of the year (or 52 minutes), whereas in the frontal event this rain rate is exceeded for approximately 0.2% of the event duration. A 60 mm/hour rain rate is exceeded for approximately 0.001% of the time in both the annual curve and the frontal event curve.

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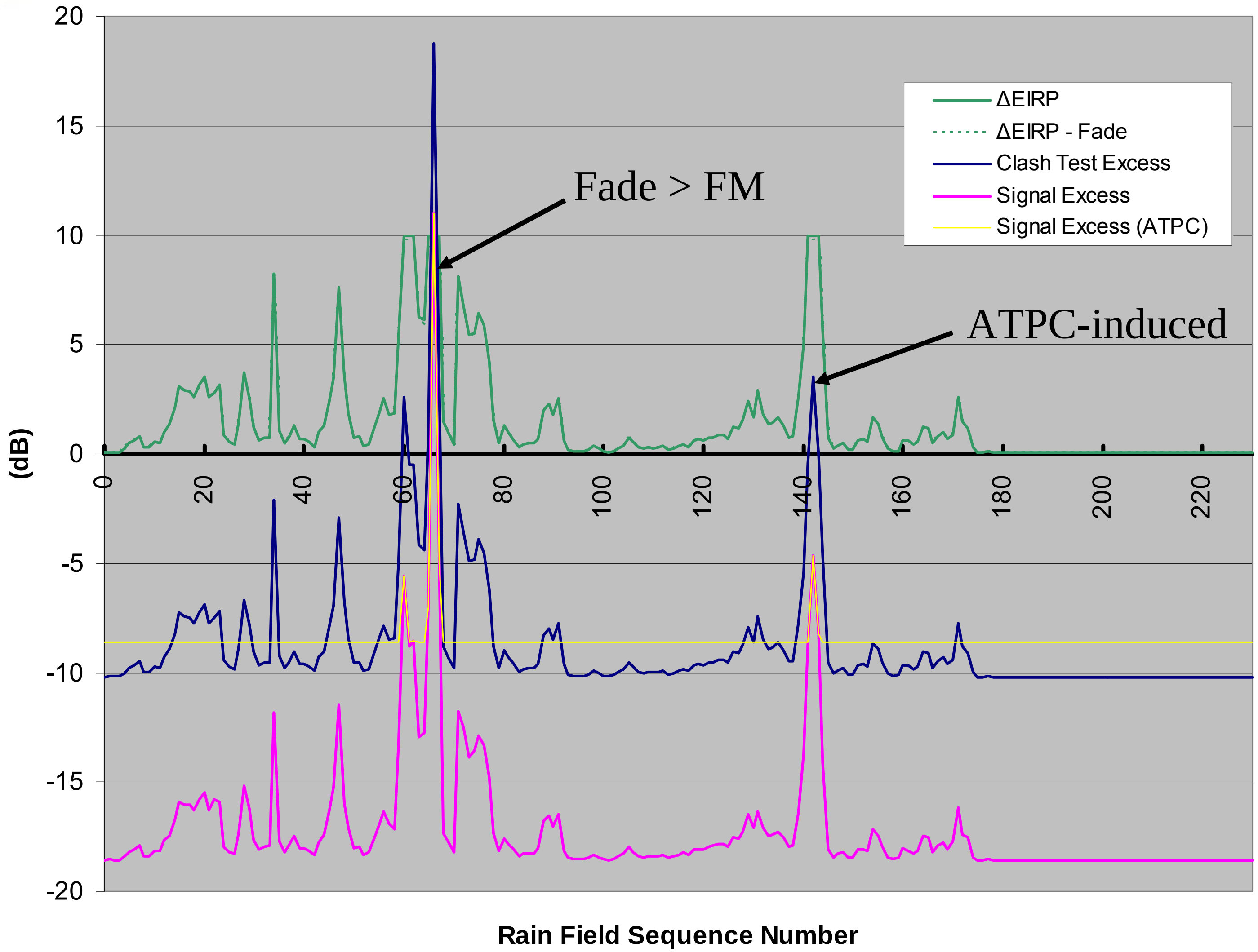
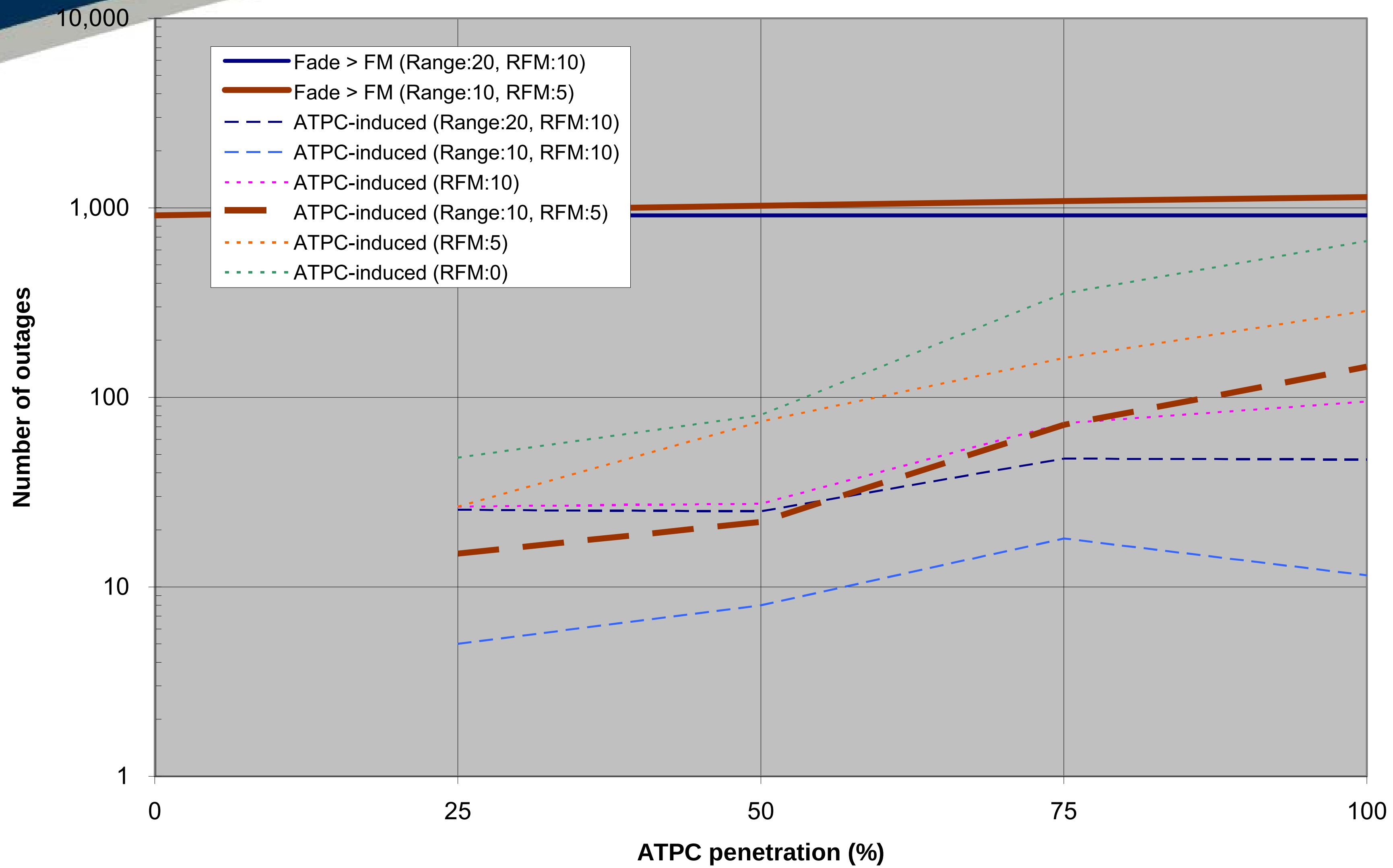
Two types of outage

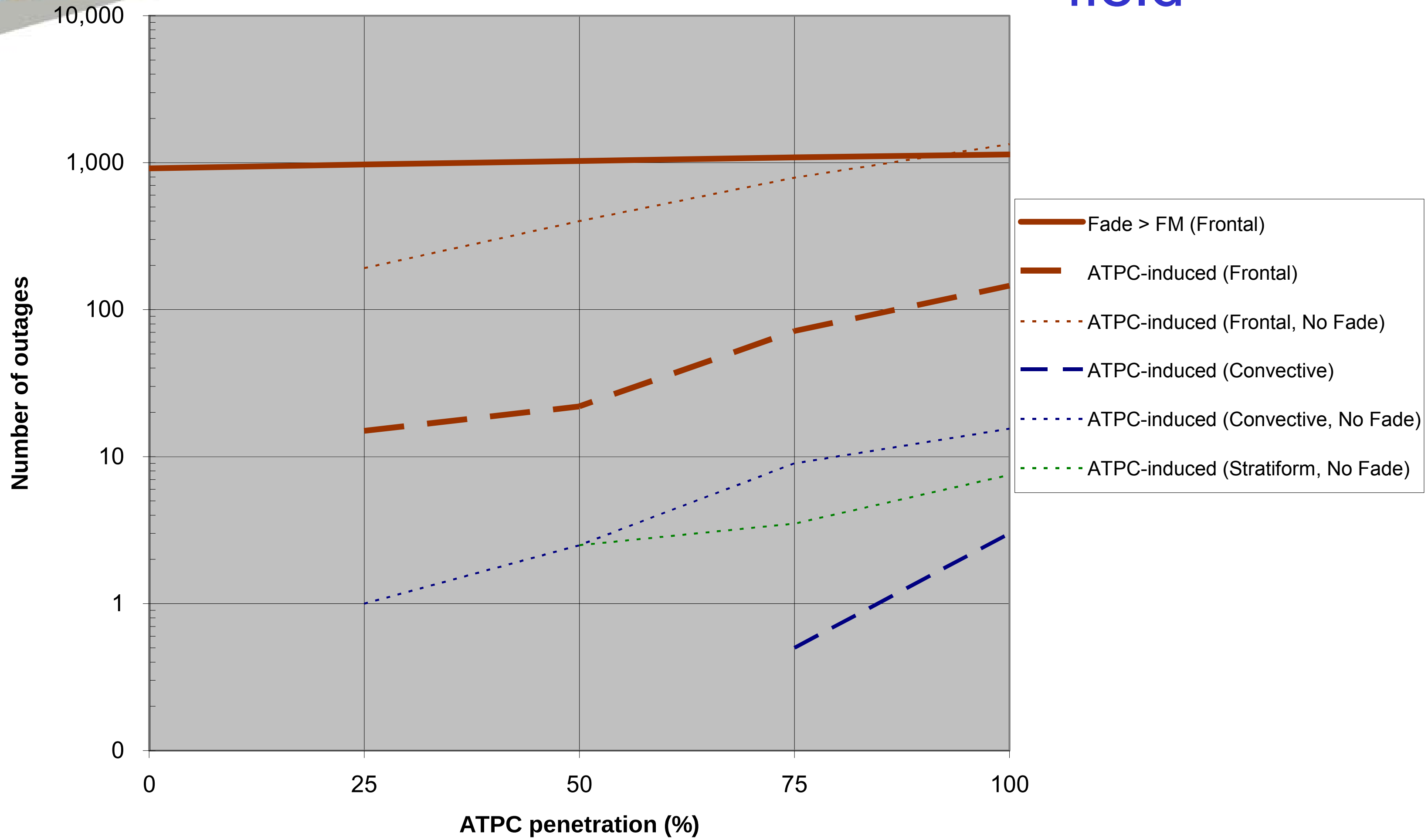


Outages vs ATPC penetration



ATPC-induced outages rise as proportion of ATPC links increases

Correlation in the rain field



Rain fade on interfering link is removed and ATPC-induced outages increase dramatically. Correlated fading on the interfering path is a significant mitigating factor for ATPC-induced outages

Mitigation of ATPC-induced outages

Can changes to the planning process be made that retain the efficiency gains but reduce the number of ATPC-induced outages?

- Increasing the fade margin for all links.
- Increasing (or decreasing) the required W/U ratios for all links.
- Increasing the interference margin.

Best choice is to adjust W/U when planning, but assume the original W/U values when performing the rain analysis. Then increasing W/U now removes some, but not all, of the ATPC-induced outages. (Note that adjusting W/U, while leaving RSL unchanged, has no effect on the number of direct outages.)

Investigation using annualised rain (1)

For the annualised rain, a plan with known link availabilities was generated and tested to see whether the links respond in the appropriate way to the scaled, mixed, annualised collection of rain fields.

The results from this show that a plan constructed with the objective of achieving a 0.01% unavailability has, when exposed to simulated annualised rain, a measured unavailability of 0.008%.

Using the annualised database, simulations were run for one scenario, with ATPC range = 10 dB and remote fade margin = 5 dB, and were compared with the results for the same scenario using the measured frontal rain data which was scaled to have a distribution equivalent to the annualized database. The frequency plan for the link assignment assumed that all the links were located in central London.

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Investigation using annualised rain (2)

The number of extra ATPC-induced outages relative to the number of direct outages is 12% for the measured frontal rain event.

For the scaled frontal rain simulation the percentage falls from 12% to 5%. The fall is because the plan has less protection against rain, as it has London links “moved” to a drier part of the country, Chilbolton in Hampshire. The frontal event therefore causes more direct outages (almost twice the number of the original), which then reduces the relative importance of the extra ATPC-induced outages, which don't increase as fast as direct outages.

The number of extra outages in the annual rain case is then 2.6%. All these figures are for 100% ATPC penetration.

We believe that matching the ATPC range and the remote fade margin would reduce the percentage of extra ATPC-induced outages even further.

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Conclusions

Using ATPC in the 38 GHz band gives significant improvements in spectrum efficiency measured by:

1. the increase in the number of links assigned to channel 1 (from ~50% to ~70%)
2. 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; however, the outages cannot be wholly eliminated.

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