A technique for reconstructing two-dimensional rainfall fields from terrestrial microwave links

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Abstract

The opportunistic use of terrestrial microwave links for the measurement of rainfall has the potential to provide several improvements over conventional radar techniques. We present a technique that is capable of producing two-dimensional rainfall fields from a number of measurements of integrated specific attenuation. The approach presented here is able to provide estimates from heavily quantized measurements; the algorithm is also capable of providing images with a varying grid-scale to provide higher-resolution outputs where there is a higher-density of links.

1. Introduction

There has long been significant interest in the use of terrestrial point-to-point microwave links; we concentrate on a procedure that attempts to calculate a spatial 'image' of the rainfall rate using a number of microwave terrestrial links. Each of these links provides an estimate of the path-integrated specific-attenuation.

There are two types of data sources; either purpose-deployed links which are typically simple CW links deployed solely to measure the attenuation along the path, these links will typically sample at a high temporal resolution and have low attenuation quantization [1,2].

The second type of data source is through the 'parasitic' use of communication networks. Many communication systems such as cellular networks use microwave links to provide an aggregated 'backhaul' capacity to the network. These links have the advantage over purpose-deployed links since they can have a very high density; typical link densities have been quoted of the order from 3 links per km^2 to 0.3 links per km^2 [3] whilst there are in excess of 14,000 38 GHz links operating in the UK alone [4] an average density of approximately 0.055 links per km^2 in just one frequency assignment.

An approach using terrestrial links potentially offers a number of advantages over weather radar systems. At long ranges radars provide an estimate of the rainfall at altitude, typically at a range of 75 km this estimate can be at an altitude of 1.8 km and at a range of 100 km this can increase to over 2.5 km. In general the rainfall rate of interest is that at ground-level, the rainfall rate at altitude may not always be a good indication of the surface rainfall-rate, phenomena such as evaporation and drop-sorting can result in significant variation.

Other advantages over radar systems are the mitigation of effects such as radar beam-blockage and clutter. Some environments are not particularly suitable for the use of radars; urban environments typically exhibit high-levels of clutter making high-resolution radar estimates in urban environments very difficult. Conversely urban environments often require high-resolution assessments of rainfall particularly for the assessment of flood risk and other urban hydrological phenomena. Mountainous terrain is also an area where radar estimates of rainfall can be difficult to achieve, due to the blockage and clutter in these areas.

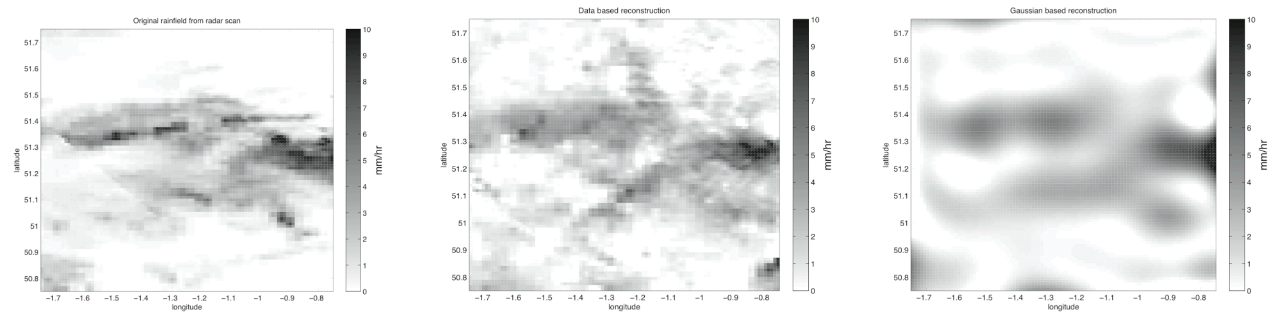
Radar systems also have temporal inconsistencies associated with each radar scan; the time taken to physically beam-steer and change azimuth can be significant. Hence, the radar scan is only 'instantaneous' at one location; the complete scan is not instantaneous. An approach based around the assessment of rainfall using path-integrated links could provide temporally consistent, high-temporal resolution assessment of the rainfall rate.

2. Example results

Several examples of the algorithm are included for an example experiment on 7th July 2004 at 22:00 (UT), the reconstruction domain covered a 1-degree square pixel centered on 51.25N, 1.25W – an area of approximately 100km x100km. Link attenuation was acquired for 400 links, approximately 70% of these links had attenuations less than 1dB, whilst 90% had attenuation less than 3dB and the maximum attenuation was 12dB. The maximum link length was 10km.

Two versions of the algorithm were used to create the reconstruction rainfall field, one using a data-driven approach the other using a Gaussian synthetic rainfall approach, the 1km radar composite from the UK Met Office is shown in Figure 1, along with these reconstructions.

The algorithm has no requirement for square pixels of uniform scale hence it is possible to generate multi-scale forecasts where the pixel size of the reconstruction is determined by the local link-density. An example multi-scale reconstruction is shown in Figure 2, this covers the same area and time frame as Figure 1.



1km UK Met Office radar composite | Data driven reconstruction | Gaussian reconstruction

Figure 1. Example reconstructions: 22:00 (UT) 7th July 2004

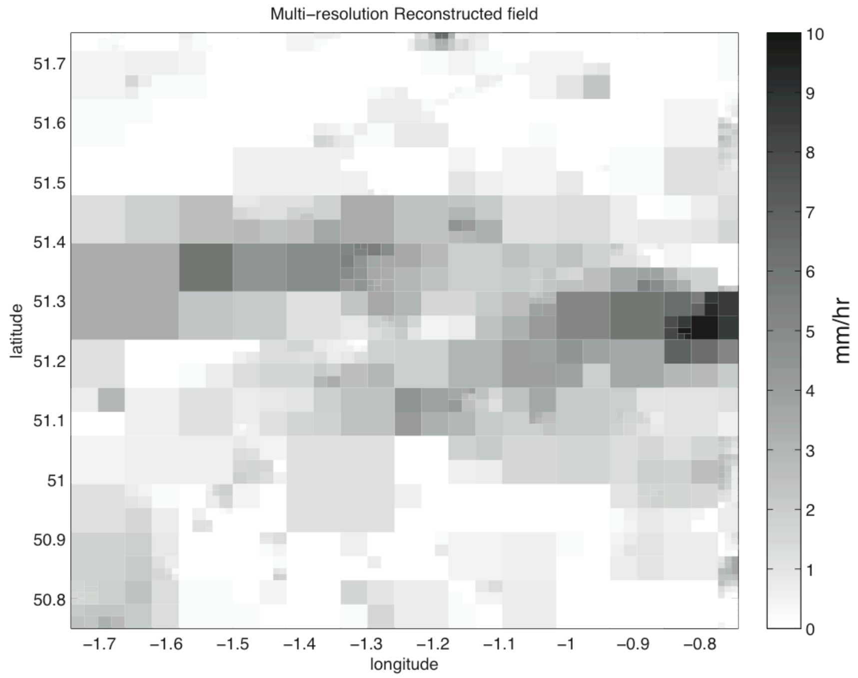


Figure 2. Aexample multi-scale reconstruction.

3. Conclusions

We will demonstrate a technique for producing two-dimensional estimates of the rainfall field. These estimates are can be generated even with heavily quantized data, quantization levels of 2dB results in an increase in the reconstruction error of around 4% whilst quantization levels of 4dB results in an error of approximately 14%. The algorithm does not require square pixels or a continuous grid and hence the reconstruction can be adapted to density of the link coverage.

The approach can be used to supplement traditional radar networks in areas where coverage is poor or areas that suffer from significant issues such as beam-blockage and clutter. In areas where there is no radar coverage it may be possible to cost-efficiently provide two-dimensional estimates of rainfall rate which are sufficient for most users.

5. References

1. Atlas, D. and C. W. Ulbrich, "Path- and Area-Integrated rainfall measurement by microwave attenuation in the 1-3 cm band", *J. Appl. Meteorol.*, vol. 16, December, 1977, pp 1322-1331.

2. Giuli, D., L. Facheris and S. Tanelli, "Microwave tomographic inversion technique based on a stochastic approach for rainfall fields monitoring", *IEEE Trans. Geo. Rem. Sens.*, vol. 37(5), December, 2007, pp 2536-2555.

3. Messer, H., A. Zinevich and P. Alpert, "Environmental monitoring by wireless communication networks", *Science*, December, 2006.

4. Callaghan, S. A., I Inglis and P. Hansell, "The impact of introducing Automatic Transmit Power Control in P-P fixed service systems operating in bands above 13 GHz", CCLRC and OfCOM, 2006.