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Estimating rainfall through a network of radiobase stations and tomographic processing in urban area: impact of link density

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More than one decade ago, our group at the University of Florence showed that path-integrated attenuations measured simultaneously at microwaves along different radio links can be profitably exploited to retrieve the two-dimensional pattern of rainfall and to provide accurate estimates of the average area rainfall at ground. The requirement is an adequate tomographic processing procedure. In 'normal' conditions, namely when a dedicated radio link infrastructure must be conceived and built with the exclusive purpose of monitoring rainfall (e.g. in a narrow valley), the tomographic procedure must be able to deal with a basic practical/economic limitation and to overcome it. Such limitation is related to the small number of radio links that can be realistically employed in the monitored area, and to the consequent fact that the inversion problem (i.e. passing from an attenuation vector to a 2D rainfall field) is heavily ill-conditioned.

A mobile communication system infrastructure (i.e. GSM, GPRS, UMTS) in an urban area constitutes a unique opportunity for rainfall tomographic monitoring, since it can be exploited to generate a high link density rainfall monitoring network, with an enormous potential in terms of areal accuracy and time resolution. In fact, the number of possible microwave radio links of an urban radio base network is much higher than the number of links that is generally sufficient to provide a quite good estimate of a specific attenuation map induced by rainfall. Furthermore, the frequencies of the channel services in Italy fall around 18, 23, and 38 GHz, allowing in theory multifrequency measurements that cover a wide range of rainfall intensities. However, the density and the crossings of the radio links can be highly irregular. The new algorithm developed adopts a tomographic approach that faces this problem, and has been tested on simulated specific attenuation (K) maps that have been generated based on true radar data gathered by the POLAR55 C polarimetric Doppler weather radar installed in Rome. We ran simulations over the radar-derived K maps by applying the new tomographic algorithm to the current radiobase station distribution in the town of Florence. We simulated the radio link path-integrated attenuation measurements by using the true polarimetric weather radar measurements, to which the well known Z-K relationships were applied. The specific attenuation maps are then used to simulate the power attenuation measurements along the true microwave radiolink network. The results provided by the simulation are extremely encouraging, showing an excellent reconstruction performance of the tomographic algorithm already when exploiting a fraction of the total number of possible links offered by the urban radio base network. However, it is obviously also of interest to avoid to overcharge the tomographic algorithm with an input attenuation vector carrying more elements than needed to obtain a good estimate of the K field. Therefore, we also focus on the analysis of the degradation of the reconstruction performance when the number of links is reduced (according to a pre-defined strategy), trying to identify the minimum level of link density required to obtain sufficiently accurate reconstructions through the proposed tomographic procedure.