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Expected performance of interferometric air-shower measurements with sparse radio-antenna arrays

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Inclined air showers open the window for the radio detection of ultra-high-energy cosmic rays with km-sparse radio-antenna arrays. The potential of those measurements would improve greatly with an accurate reconstruction of the depth of the shower maximum $X_{\max}$. However, traditional methods using the lateral signal amplitude distribution at the ground to reconstruct $X_{\max}$ with radio antennas developed for vertical air showers lose their sensitivity. A recently proposed interferometric technique promises measurements of the depth of the shower maximum $X_{\max}$ with an intrinsic accuracy of 3 g cm^{-2} for very inclined air showers, however, without considering instrumental uncertainties.

In this contribution, we evaluate the potential of interferometric $X_{\max}$ measurements of (simulated) inclined air showers with realistically dimensioned, sparse antenna arrays and account for imperfect time synchronisation between individual antennas. We find a strong correlation between the antenna multiplicity (per event) and the maximum acceptable inaccuracy in the time synchronisation of individual antennas. We formulate prerequisites for the design of antenna arrays for the application of interferometric measurements: For data recorded with a time synchronisation accurate to 1 ns within the commonly used frequency band of 30 MHz to 80 MHz, an antenna multiplicity of $>\sim 50$ is needed to achieve an $X_{\max}$ reconstruction with an accuracy of 20 g cm^{-2}. This multiplicity is achieved measuring inclined air showers with zenith angles $\theta \geq 77.5^{\circ}$ with 1 km spaced antenna arrays, while vertical air showers with zenith angles $\theta \leq 40^{\circ}$ require an antenna spacing below 100 m. Furthermore, we find no improvement in the $X_{\max}$ resolution applying the interferometric reconstruction to simulated radio signals at higher frequencies, i.e., up to several hundred MHz.

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