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Derivation of Z-R equation using Mie approach for a 77 GHz radar

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The ETSI (European Telecommunications Standards Institute) defines the frequency band around 77 GHz as dedicated to automatic cruise control long-range radars. This work aims to demonstrate that, with specific assumption and the right theoretical background it is also possible to use a 77 GHz as a mini weather radar and/or a microwave rain gauge.
To study the behavior of a 77 GHz meteorological radar, since the raindrop size are comparable to the wavelength, it is necessary to use the general Mie scattering theory. According to the Mie formulation, the radar reflectivity factor Z is defined as a function of the wavelength on the opposite of Rayleigh approximation in which is frequency independent. Different operative frequencies commonly used in radar meteorology are considered with both the Rayleigh and Mie scattering theory formulation. Comparing them it is shown that with the increasing of the radar working frequency the use of Rayleigh approximation lead to an always larger underestimation of rain. At 77 GHz such underestimation is up to 20 dB which can be avoided with the full Mie theory.
The crucial derivation of the most suited relation between the radar reflectivity factor Z and rainfall rate R (Z-R equation) is necessary to achieve the best Quantitative Precipitation Estimation (QPE) possible. Making the use of Mie scattering formulation from the classical electromagnetic theory and considering different radar working frequencies, the backscattering efficiency and the radar reflectivity factor have been derived from a wide range of rain rate using specific numerical routines. Knowing the rain rate and the corresponding reflectivity factor it was possible to derive the coefficients of the Z-R equation for each frequency with the least square method and to obtain the best coefficients for each frequency. The coefficients are then compared with the ones coming from the scientific literature. The coefficients of a 77 GHz weather radar are then obtained. A sensitivity analysis of a 77 GHz weather radar using such Z-R relation is also studied.
The work shows that the right knowledge of Z-R equation is essential to use such a specific radar for the estimation of rainfall. The use Mie scattering theory is necessary for a 77 GHz radar in order to avoid the heavy underestimation of rainfall.