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A new definition of a coordinate independent observer in relativistic electrodynamics

We are interested in the perception of the electromagnetic phenomenon by observers that are more general than standard inertial observers in flat MINKOWSKI space-time. We model a relativistic observer as (principal) fibre bundle, where the fibres correspond to world lines of test particles and the base space defines the observer's relative "space". An EHRESMANN connection on the bundle splits local tangent spaces into "space"- and time subspaces. The time subspaces point in direction of the world lines, and the "space" subspaces are their orthogonal complements, according to the hypothesis of locality. A section map on the bundle defines a time synchronization. The curvature of the connection is a measure of the non-integrability of the local "spatial" subspaces. If the connection is flat, it allows for a section that is orthogonal to the world lines in all points, hence a global EINSTEIN time-synchronization.

Time synchronization can be seen as gauge on the bundle, and the formalism of gauge theories provides the right tools. Gauge potential and curvature have a kinematic interpretation as velocity and vorticity fields. This approach encompasses all meaningful spatial-temporal decompositions of space-time. With this setting we split electromagnetic field entities accordingly and describe the effect of relative motion on measurable quantities. We will present the three plus one-dimensional form of MAXWELL's equations and the constitutive relation and analyze SCHIFF's treatment of his 1939 paradox.

In our view, the coordinate-free approach brings to light the individual layers of mathematical structure and their physical significance, and generally favours structural considerations over technical ones. We emphasize, however, that our findings can be readily translated into classical RICCI calculus, whereby all textbook results can be recovered.