There are both philosophical and numerical problems with the use of radiance. These problems are often related to the fundamental limitations of the concept of radiance. This section briefly addresses those limitations.

First, recall the operational definition of radiance from the Level 1 Section on Radiance:

$$L(\vec{x}, t, \hat{\xi}, \lambda) \equiv \frac{\Delta Q}{\Delta t \, \Delta A \, \Delta \Omega \, \Delta \lambda} \,.$$

There is nothing wrong with this definition, although the value of the measured radiance will depend on the sizes of the time interval, area, solid angle, and wavelength band being considered. The problems arise if this definition is squeezed too hard, e.g., by taking the limit as the solid angle goes to zero. The situation is analogous to the operational definition of the mass density of a substance as being $\Delta M/\Delta V$, where ΔM is the mass of substance in a volume ΔV. You cannot let the volume ΔV go to zero because, physically, the volume eventually becomes smaller than even a single molecule of the material and the ratio becomes meaningless. The trick, in practice, is not to let ΔV be so small that the $\Delta M/\Delta V$ ratio begins to fluctuate because the number of molecules in ΔV is noticeably affected by random thermal fluctuations, or even becomes less that one. If you keep in mind that ΔV can be "small" but not go to zero, the concept of density is very useful, as is that of radiance.

A question then arises: "What is the radiance of a collimated beam?" The answer is that the radiance of a perfectly collimated beam is not defined because $\Delta\Omega$ would be zero while the energy in the beam, ΔQ, remains finite. [Or, if you wish, the radiance becomes mathematically a Dirac delta function, but Dirac delta functions are not measurable physical quantities.] You can define (and measure) the radiance of a beam of light only if it has some divergence in direction.

Likewise, you cannot define the radiance emitted by the surface of a point source because ΔA becomes zero even though the point source is emitting a finite amount of energy. [Here ΔA is the area of the surface emitting the energy. See the Level 2 discussion of surface radiance.] That is why point sources are described by their intensity, which is power emitted per unit solid angle.

When doing Monte Carlo calculations you always have to deal with finite solid angles and finite surface areas when collecting the simulated "photons" or rays as they bounce around. You cannot tally the number of rays hitting a point or traveling within a solid angle of size zero. [However, backward Monte Carlo techniques can allow you to simulate point detectors and collimated detectors under certain circumstances.]

If you are a hard-core physicist, radiance does not exist. Peruse, for example, standard texts like *Introduction to Electrodynamics* by Griffiths (1981), *Absorption and Scattering of Light by Small Particles* by Bohren and Huffman (1983), or *Optics* by Hecht (1989) and you will find no mention of either radiance or solid angle. This is because what exists in nature is not radiance but electric and magnetic fields, which are described by Maxwell's equations. Quantities of practical interest, such as the electromagnetic energy crossing a surface or scattered by a particle, can be computed using Maxwell's equations and derived quantities such as the Poynting vector. Philosophically speaking, any problem solved by thinking about radiance can be solved with better accuracy and without fundamental limitations by working with electromagnetic fields.

Why, then, do people use radiance? The reason is simple: It is usually exceedingly difficult if not impossible to compute the electromagnetic fields for situations of practical interest. The electric and magnetic fields are vector quantities, and solving Maxwell's equations with appropriate sources and boundary conditions for natural water bodies is almost always beyond the realm of reasonable computation. Moreover, much of the information contained in the electric and magnetic field vectors, such as the phases of the fields, is not needed unless diffraction or coherent scattering are of interest.

You can, however, get a good-enough answer for most (but not all) practical problems by working with the rather contrived but simpler concept of radiance. You just have to remember, for example, not to let solid angles or detector areas go to zero. Likewise, you have to remember that radiance cannot be used for solving problems that depend on the phase of electromagnetic waves, e.g. for problems such as diffraction or coherent backscatter. [However, effects such as diffraction and coherent backscatter can be included within radiance-based calculations to the extent that they can be parameterized by the volume scattering function.] It is also wise to remember that *radiance is defined within the conceptual framework of geometric optics*. You can solve a lot of, but not all, optics problems using geometric optics and ray tracing, but now and then geometric optics is inadequate for the task at hand. Whenever geometric optics or radiative transfer theory fail, you have to get out Maxwell's equations and start calculating electric and magnetic fields, keeping track of both phases and amplitudes, and that is not easy.