7.5.1 Reflection- and absorption-parameters

The descriptive parameters of waves, and associated reflection and absorption, were already elaborated in Chapters 1 and 2 – however, assuming that not every reader seeks to struggle through those chapters, a short summary is given in the following.

Via the plucking/picking of the string, it is deflected with the **force** F in the transversal direction. This plucking force delivers the energy that – after release – makes the string vibrate (oscillate). The unit for the force is the Newton (N) with $1\,\mathrm{N} = 1\,\mathrm{kg \cdot m / s^2}$ in the mks-system. To characterize the motional magnitude of the oscillation, the **(particle-) velocity** is used (besides displacement and acceleration) – it is not to be confused with the propagation speed. The product of force and particle-velocity calculates the **power** P given in units of Watt (W); 1 W = 1 Nm/s. Temporal integration of power yields the **energy** E, with the associated unit Ws = Nm. The typical excitation energy of a string amounts to a few milli-watt-seconds (mWs). Caution should be exercised with regard to the letter m, since it represents the abbreviation for both the unit of length *meter*, and the prefix *milli* ($1/1000^{th}$).

The quotient of force and particle-velocity of a propagating wave forms the **wave-impedance**: $Z_W = F / v$. However, Z_W does not stand for the quotient of the force acting on a little piece of string and the velocity of this piece of string, since these magnitudes could have resulted from superposition of several waves. For example, the velocity in a vibration node is always zero – but that does not mean at all that the wave impedance is zero at that location. Rather, the node generated in standing waves is the result of two waves running in opposite directions. The wave impedance is defined only for the individual wave. In steel strings, the wave impedance is about 1 Ns/m; more exact data may be found in the appendix.

As a propagating wave hits an obstacle, part of the wave power is reflected. An obstacle is given by a location in the medium the wave travels in where the wave impedance differs from that of the string, as is the case in particular for the string bearings (bridge, and nut or fret). The **degree of reflection** denotes the portion of the wave power that is reflected – the non-reflected portion is absorbed. Besides the degree of reflection there is also the reflection factor that is required for calculations involving force and velocity. If, for example, 25% of the wave power is reflected, this implies that the force of the backward-running (reflected) wave is 50% of that of the forward-running wave. In this case, the particle-velocity of the backward-running wave is also 50% of that of the forward-running wave, since both waves are connected via the wave impedance (see above). From this we get: the degree of reflection is the square of the reflection factor. The **degree of reflection** and the **degree of absorption** add up to 1. Thus, 25% degree of reflection pertains to 75% degree of absorption

The formula representations for reflection factor and degree of reflection are not always handled uniformly: often r is used for both. To avoid mix-ups here, we will use r for the reflection factor, and r^2 for the degree of reflection. Alternatively, the terms “degree of energy reflection” r_E and “degree of power reflection” r_P are made use of – the magnitudes of both quantities are equal.

Due to the law of energy conservation, the degree of reflection cannot be larger than 1. In guitars, values of just shy of 1 (e.g. 99%) are typical. In some frequency ranges, however, there may be much absorption – the vibration energy is efficiently transmitted into the bearing, and it either is converted directly into heat, or (partially) radiated as sound.

