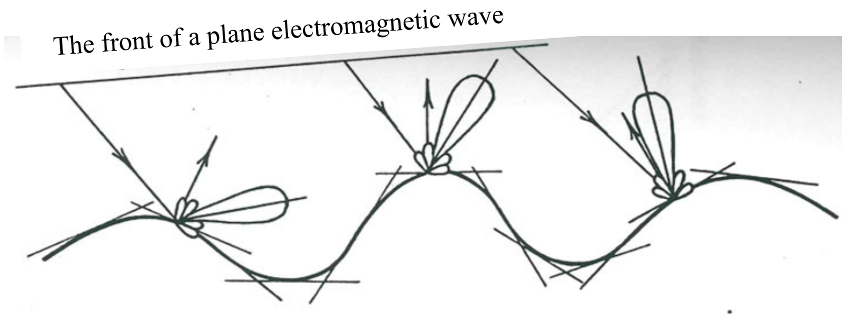
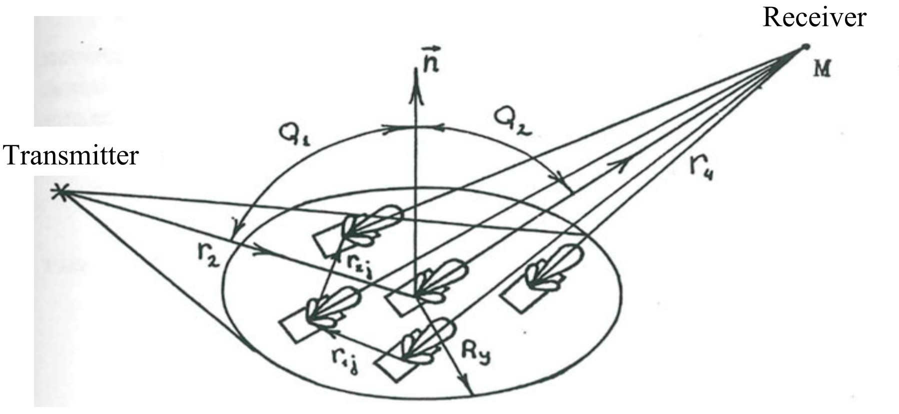
The reflection of a plane electromagnetic wave from a square surface area

Let the length of a plane monochromatic electromagnetic wave λ be much less than the characteristic dimensions of the surface irregularities of a solid or liquid substance conducting electric current (i.e., $\lambda \ll r_{cor}$, where r_{cor} is the autocorrelation radius of the heights of the bumps in the reflecting surface). In this case, the uneven surface can be divided into many flat square sections (facets). Consider the reflection of the rays of the electromagnetic wave from each facet separately (Figure A.1.1 *a*,*b*).



a)



b)

Fig. A.1.1 Scattering of an electromagnetic wave on a surface approximated by smooth square sections (facets). *a*) The maximum of the main lobe of the scattering diagram of each facet is directed according to the laws of geometric optics: lies in the plane of incidence and the angle of reflection is equal to the angle of incidence; *b*) Only the main lobes of the scattering diagrams whose facets are oriented accordingly are directed towards the receiver antenna

The beam of an electromagnetic wave here refers to a cylinder whose axis connects the source of the electromagnetic wave to the center of the reflecting facet, and the diameter of the base of this cylinder approximately coincides with the size of one of the sides of the b_n square facet.

We define the scattering diagram of a flat monochromatic electromagnetic wave (EMW) on a single facet that perfectly conducts an electric current. Let's assume that the radiation point (emitter, Fig. A.1.1*b*) and the observation point (receiver) are located at a great distance from the facet (i.e. $b_n \ll r_2$ and $b_n \ll r_4$), so that the EMW rays incident on the facet and reflected from the facet can be considered almost parallel. In this case, the signal sent from any point on the square facet to the receiver antenna has the form

$$E_i(x,y) = \frac{E_m}{r_1}\exp\left\{i\left(\omega_1 t + \frac{2\pi}{\lambda}\begin{bmatrix} x(\cos\nu\sin\omega + \cos\vartheta\sin\gamma) + \\ + y(\cos\nu\cos\omega + \cos\vartheta\cos\gamma) - r_2 \end{bmatrix}\right)\right\}, \tag{A.1.1}$$

where x and y determine the coordinates of each point on the square facet;

E_m is the amplitude of the monochromatic electromagnetic field near the emitter;

r_1 is the distance from the source of EMW to the center of the facet (Figure A.1.1*b*);

r_2 is the distance from the center of the facet to the antenna of the receiver (Figure A.1.1*b*);

ω_1 is the oscillation frequency of a monochromatic electromagnetic wave;

ϑ, γ are angles that specify the direction of the EMW ray incident on the facet (Figure A.1.2);

ν, ω are the angles that specify the direction of the EMW ray reflected from the facet.

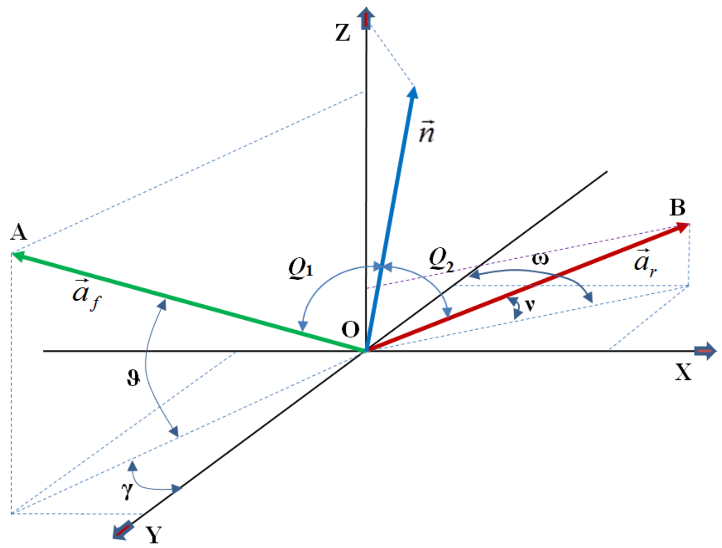


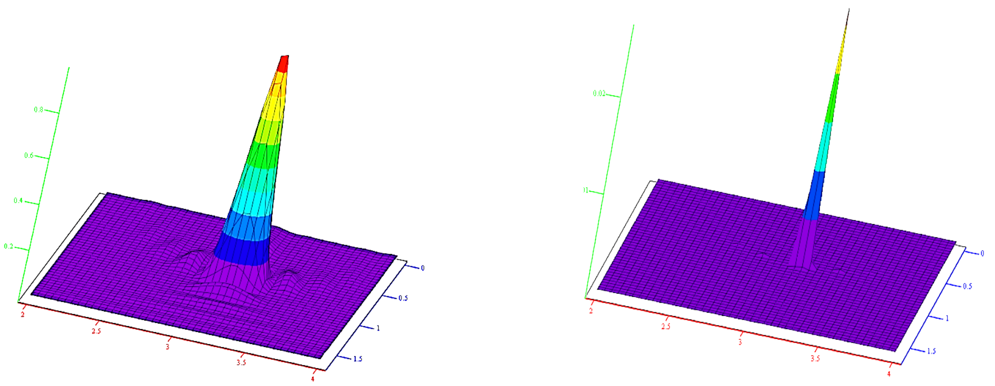
Fig. A.1.2 Angles ϑ, γ determine the direction of the EMW ray incident on the facet; angles ν, ω determine the direction of the EMW ray reflected from the facet

$$E_\Sigma = \iint_{b_n^2} E_i(x,y)dxdy = \frac{\sin\left\{\frac{2\pi b_n}{\lambda}(\cos\nu\sin\omega + \cos\vartheta\sin\gamma)\right\}}{\frac{2\pi b_n}{\lambda}(\cos\nu\sin\omega + \cos\vartheta\sin\gamma)} \times$$
$$\times \frac{\sin\left\{\frac{2\pi b_n}{\lambda}(\cos\nu\cos\omega + \cos\vartheta\cos\gamma)\right\}}{\frac{2\pi b_n}{\lambda}(\cos\nu\cos\omega + \cos\vartheta\cos\gamma)} \times \frac{E_m}{r_1}\exp\left\{i\left(\omega_1 t - \frac{2\pi}{\lambda}r_2\right)\right\}. \tag{A.1.2}$$

The first and second multipliers in the expression (A.1.2), squared, is the desired power scattering diagram of a flat, monochromatic EMW from a perfectly conducting square sections of the surface (facets)

$$D_r(\nu,\omega/\vartheta,\gamma)=\frac{\sin^2\left\{\frac{2\pi b_n}{\lambda}(\cos\nu\sin\omega+\cos\vartheta\sin\gamma)\right\}}{\left[\frac{2\pi b_n}{\lambda}(\cos\nu\sin\omega+\cos\vartheta\sin\gamma)\right]^2}\frac{\sin^2\left\{\frac{2\pi b_n}{\lambda}(\cos\nu\cos\omega+\cos\vartheta\cos\gamma)\right\}}{\left[\frac{2\pi b_n}{\lambda}(\cos\nu\cos\omega+\cos\vartheta\cos\gamma)\right]^2}. \tag{A.1.3}$$

The scattering diagrams calculated using the formula (A.1.3) are shown in Figure A.1.3 (see Appendix 12)



a) $\vartheta = 45^0$, $\gamma = 0^0$, $b_n/\lambda = 3$ *b*) $\vartheta = 45^0$, $\gamma = 0^0$, $b_n/\lambda = 50$

Fig. A.1.3. Power scattering diagrams of a flat, monochromatic EMW from a perfectly conducting square sections of the surface (facets). The calculations are performed according to the formula (A.1.3) using the MathCad software

The cross section of the scattering diagram (A.1.3) in the plane of incidence and reflection of the EMW beam shown in Figure A.1.4.

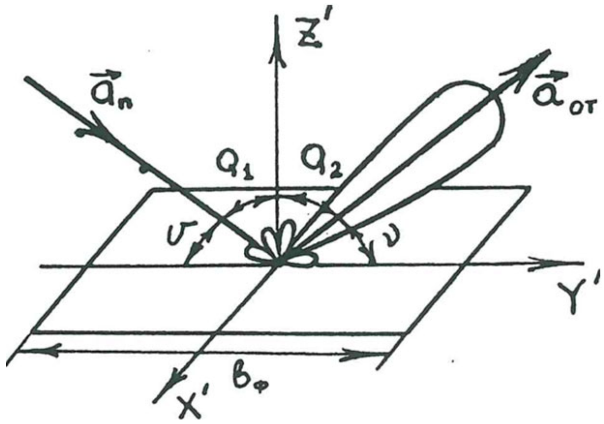


Fig. A.1.4 Cross section of the scattering diagram of a beam flat electromagnetic wave from a flat square surface area (facet) conducting an electric current

From the scattering diagrams (DR) shown in Fig. A.1.3, it is seen that with an increase in the ratio b_n / λ, the main lobe of the DR becomes thinner and elongates, and the side lobes disappear. For large b_n with respect to λ (i.e., when $b_n / \lambda \rightarrow \infty$), the scattering diagram (A.1.3) degenerates into a delta function, i.e. the EMW beam reflected by the large facet becomes infinitely thin. In this case, the laws of reflection of a light ray from a facet (i.e., the laws of geometric optics) completely coincide with the laws of elastic reflection of particles from a solid surface under similar conditions (i.e., when the particles are much smaller than the dimensions of a solid surface).

In other words, in this case, the behavior of the light beam completely corresponds to the behavior of the particle (which can be called a photon). A photon is reflected almost lossless from a "mirror" surface according to the laws of geometric optics, just as elastic electrons or protons are reflected from a solid surface. Energy losses due to heating of the reflecting surface during collisions with particles and other secondary effects are not taken into account in the model under consideration.

Therefore, in this article, microparticles are any particles: fermions (e.g., electrons) and bosons (e.g., photons), whose sizes are much smaller than the characteristic irregularities of the reflecting surface (Kirchhoff approximation), and reflected from this surface according to the laws of geometric optics.

All conclusions made in this article relate to both elastic particles and electromagnetic radiation (light) rays, under the above conditions.

In connection with the foregoing, all conclusions made in this article relate to both elastic particles and EMW (light) rays, if the above conditions are met.