REVIEW

of the member of the dissertation council Andonian, Gerard on the thesis of Simakov Evgenii Sergeevich on the topic «Radiation of charged particle bunches in the presence of conductive corrugated structures with a small period», submitted for the degree of candidate of physical and mathematical sciences in the specialty 1.3.4. Radiophysics.

The thesis focuses on studying radiation generated from charged particle bunches moving in the presence of conductive corrugated structures. The problems under consideration aim to investigate the so-called “longwave” radiation where the wavelengths of the electromagnetic waves are much greater than the corrugated structure periodicity. Under this approximation, a solution can be obtained by using the method of equivalent boundary conditions (EBC), where the corrugated structure geometry is equivalently replaced by a smooth, anisotropic surface characterized by a certain matrix impedance.

It is worth mentioning that, typically, radiation from charges moving in the presence of periodic structures is investigated at wavelengths that are comparable to, or less than, the period. In this case, the bunch generates Smith-Purcell radiation (SPR) which is a well-understood and well-studied physical phenomenon. Problems concerning SPR require specific approaches to solving which are principally different from the EBC method used in the “longwave” problems considered in this thesis. Also, in contrast to SPR, the “longwave” range of the spectrum has not been studied as much in the scientific literature. However, as shown in the thesis, research in this direction is very compelling from a scientific standpoint. In particular, one of the main results of the thesis is that a charge moving in the presence of a planar corrugated structure can generate surface waves. This radiation is principally different from SPR and is not excited in the spectrum range corresponding to SPR. Due to this fact, the electromagnetic field of the surface wave requires detailed analysis which is presented in the thesis.

A short summary of the thesis follows below.

In the first chapter, the author investigates the radiation of a charged particle bunch moving in the presence of an unbounded planar corrugated structure. In Chapter 1, the structure considered has shallow corrugations, i.e. the wavelengths under consideration are much greater than the corrugation period and depth. Two regimes of the charge motion are analyzed – first, along the surface plane (perpendicular to the corrugation direction) and, second, through the surface (perpendicular to the structure). It is shown that, in the case of longitudinal motion, an ultra-relativistic bunch generates surface waves, whereas volume radiation is absent at any charge velocity. The electromagnetic field of the surface wave is a localized impulse whose properties allow the determination of the charge bunch distribution in the longitudinal dimension. When the bunch passes through the corrugated surface, the radiation consists of both surface and volume waves. Here, the focus is on studying the surface radiation and it is shown that the waves are generated at any bunch velocity. As in the previous case, the author shows that the characteristics of the surface waves can be applied to determining the bunch longitudinal profile and the bunch length.

In the second chapter, the author studies analogous problems for the case of the deep corrugation, i.e. when the structure depth is of the same order as the inverse wavenumber. It is shown that the longitudinal charge motion results in the excitation of the surface waves for a wide

range of bunch velocities. Moreover, the radiation is more intense compared to that of the shallow corrugation, and the electromagnetic field of the surface wave has a complex structure. The author demonstrates that in this case, a bunch diagnostic is possible as well, under the condition that the charge velocity is close to the speed of light, and the corrugation depth is relatively small. In the case when the bunch passes through the corrugation, the radiation consists of both surface and volume waves as before. Analysis of the energy losses for both types of waves shows that the radiation distribution strongly depends on the corrugation depth. In particular, for the relatively deep corrugation, almost all of the radiation energy is concentrated along the corrugation grooves.

In the third chapter, the author considers the radiation of a bunch moving along the axis of a cylindrical waveguide with deeply corrugated walls. It is shown that the wave field consists of an infinite set of propagating waveguide modes. The fundamental mode, or electromagnetic field of the first mode, is studied in detail and discussed. Next, the author analyzes the diffraction of the radiation mode at the open end of the waveguide, with a flange. The analytical formulas for the field outside the waveguide are obtained by using the Wiener-Hopf-Fock formalism. Typical radiation patterns in the far field zone are obtained and analyzed. The radiation is characterized by several radiation maxima, which can be varied by changing the waveguide radius and the bunch velocity.

Considering the above findings, one can say with certainty that the research presented is of significant interest for developing fundamental concepts about radiation of particle bunches in the presence of periodic structures. The topic is highly relevant for potential applications in accelerator physics and radiation generation. First, the spatial distributions of the electromagnetic fields of the generated surface waves can be applied to developing a new method for bunch diagnostics. Importantly, the diagnostic can be practically non-invasive to the bunch, i.e. it does not perturb the bunch dynamics. In addition, the deeply corrugated waveguide can be used for the generation of intense wakefields which can be used for the acceleration of charged particles. The considered corrugated structure may be a promising alternative to a smooth waveguide with dielectric filling that has shown impressive results in the last few years in terms of high-field particle acceleration. Also, the open-ended corrugated waveguide can be applied as a source of radiation into external space reaching a frequency range that is traditionally difficult to access (GHz to THz). Finally, it should be noted that the analytical and numerical algorithms developed in the thesis can be used to calculate the fields of bunches with arbitrary shapes which is very useful as corrugated structures become widely adopted in the particle accelerator community.

The scientific novelty of the thesis consists in the fact that the radiation of charges is investigated in the “longwave” range of the spectrum. Under this approximation the author has solved several problems that were not examined previously in the literature. Specifically, the author considers the study of the “longwave” radiation of small particle bunches moving in different regimes - along and through corrugated planar surface (in the approximations of the shallow and deep corrugations), and along the axis of the cylindrical deeply corrugated waveguide. The thesis also includes the investigation of the diffraction of the radiation mode at the open end of the deeply corrugated waveguide presented in analytical form.

It is worth noting that all the results of the thesis were obtained by applying well-known analytical methods of electrodynamics, mathematical physics methods, complex variable function theory, and waveguide theory. The author showed that the use of the EBC method is justified as

well and is a very useful tool for studying complex problems relating to corrugated waveguides. The validity of the acquired results is well supported by the presented methods.

Lastly, it should be emphasized that the results have been properly disseminated to the community. The author reported at 7 conferences including well known conferences to the community such as “IPAC – The International Particle Accelerator Conference” and has published 5 articles that are peer-reviewed, all in respected journals that are included in “WoS” and “Scopus” databases.

Considering the topical relevance of the work, the novelty, and the scientific and practical significance, it is my estimation that the thesis meets all the necessary requirements, and the author, Evgenii S. Simakov, deserves to be awarded the degree of candidate of physical and mathematical sciences.

Sincerely,

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