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Abstrakt

Podstawowym celem pracy jest przedstawienie opracowanych uogólnionych metod analizy zagadnień elektrostatyki układów planarnych zarówno periodycznych jak i nieperiodycznych, zawierających skończoną ilość elementów, do celów efektywnego rozwiązywania zagadnieńbrzegowych w teorii generacji i detekcji fal akustycznych oraz analizy zagadnień brzegowych w teorii fal elektromagnetycznych dla przypadku struktur falowodowych.

(tylko na tej stronie)

Manuscript title

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Abstract

The work aims to present extensions of the developed methods used in electrostatic analysis of planar periodic and finite systems for efficient solving of variety of the acoustic and electromagnetic wave generation and scattering problems. Specifically, their generalization for application in the acoustic beam-forming analysis is reported. Moreover, certain electromagnetic wave scattering problems by periodic waveguiding structures which can be efficiently approached by these methods are also considered.

(tylko na tej stronie)

Symbole i skróty (OPCJONALNIE)

Lista symboli i skrótów użytych w pracy:

ω,Ω	-	angular frequency
f	-	temporal frequency
f_0	-	central frequency (of a transducer)
λ	-	wave-length
k	-	wave-number
Λ	-	period of strips (group of strips) or baffles (group of baffles)
K	-	spatial spectrum wave-number of periodic array of strips (baffles)
P_k	-	Legendre polynomials of the first kind
J_k	-	Bessel function of the first kind of order k
Γ	-	gamma function
φ	-	electrostatic or acoustic potential
Q	-	electrostatic charge
V	-	potential difference (voltage between strips)
σ	-	surface charge distribution
x,y,z	-	Cartesian space variables
ε_0	-	dielectric permittivity of vacuum
ε	-	effective surface dielectric permittivity
μ_0	-	magnetic permeability of vacuum
$\mathbf{E}$	-	electric field vector
$\mathbf{H}$	-	magnetic field vector
$\mathbf{D}$	-	electric induction vector
E_i	-	components of electric field, $i=x,y,z$
H_i	-	components of magnetic field,$i=x,y,z$
D_i	-	components of electric induction,$i=x,y,z$
$G(\xi)$	-	planar harmonic Green's function
$\Phi(\xi)$	-	spectrum representation of the complex (electrostatic) field function

$\Phi(x)$	-	spatial representation of the complex (electrostatic) field function
d	-	strip half-width
r,s	-	spectral variables related to the x,y spatial coordinates constrained to one Brillouin zone
p	-	acoustic pressure
ρ_a	-	mass density of the acoustic media
v_z	-	z-component (normal component) of the particle velocity
Π	-	acoustic power
Π_z	-	normal component of the acoustic Poynting vector
SAW	-	surface acoustic wave
IDT	-	interdigital transducer
BIS	-	Blotekjær, Ingebrigtsen, and Skeie expansion method
FFT	-	fast (finite) Fourier transform
SNR	-	signal-to-noise ratio
SA	-	synthetic aperture
SAFT	-	synthetic aperture focusing technique
M-SAFT	-	multi-element synthetic aperture focusing technique
STA	-	synthetic transmit aperture
MSTA	-	multi-element synthetic transmit aperture
TM	-	transverse magnetic wave polarization
TE	-	transverse electric wave polarization

Spis treści

(opcjonalna pusta strona, jeśli *Spis treści*kończy się na stronie nieparzystej)

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Wstęp

1.1. Tytuł sekcji 1.1

A manuscript submitted for publication to IPPT Reports on Fundamental Technological Research should be original work which have not been previously published and should not be under consideration for publication elsewhere. Submitted materials should be written in good English. Exceptionally, submissions of the PhD and Habilitation theses written in the language other than English are also possible, provided that they are accompanied by parallel submissions of their summaries written in good English.

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Tytuł Rozdziału 2

2.1. Tytuł sekcji 2.1

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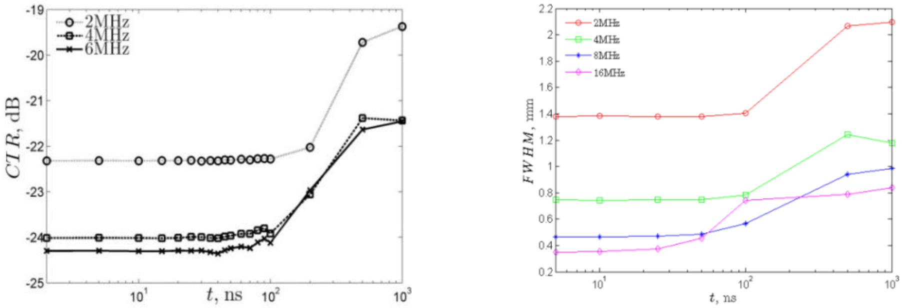

(a) (b)

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2.3. Tytuł sekcji 2.3

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Chapter	Calibri	22	36/36	Left	
Section	Calibri	16	18/12	Left	
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Paragraph	Times New Roman	11	0/0	Justified	
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Different methods of the linear phased array modeling are described in the literature.

Among them the most frequently used the beam profile modeling and point spread function modeling. The beam profile modeling is based on the intuitive representation of the array as a set of simple point sources. In the point spread function modeling the ability of the imaging system which exploits phased array transducer to visualize a point reflector (by means of certain imaging algorithm) is modeled. For this purpose the ultrasonic data from the array due to a point reflector at a particular spatial position are simulated first. Then the image of the reflector is plotted using the appropriate imaging algorithm applied to the simulated data. Both these methods must apply certain model of the individual element of the array (they are typically piezoelectric strips separated by epoxy layers). There are different methods of modeling the array element, including finite element analysis~ or Huygens principl. In the later case, usually the integration of a series of point or line sources is performed to obtain the element directivity function due of the finite size of the array element. The above approaches to modeling the array transducer assume that the individual elements respond to the incident wave pressure independently of each other yielding the electric signal proportional to the incident wave amplitude. However, since piezoelectric materials are closer to hard, and epoxy is closer to soft acoustic materials, the Bragg scattering occurs when the incident wave scatters from the array. This phenomenon necessarily distorts the local acoustic pressure on piezoelectric elements of the array affecting its electric response.

In this study the alternative approach for modeling the ultrasonic linear array transducer is developed, which is based on the rigorous full-wave analysis of the corresponding boundary-value problem for wave excitation or scattering.

The considered system, modeling a transducer array, consists of periodic acoustically hard strips (baffles) where the normal acoustic vibration vanishes, and between them there are acoustically soft domains where the acoustic pressure vanishes (or it is given constant in the excitation problem).

It should be noted, that in the classical formulation of the scattering problem, which can be found for example in the reflected and transmitted wave-fields are of primary interest and the problem is solved using Green's theorem. The unknown field on strips is represented by the series of Chebyshev polynomials, and using the Galerkin method the problem is reduced to a certain system of linear algebraic equations for unknown expansion coefficients. The scattered field (transmitted and reflected waves) is finally found as a superposition of infinite number of spatial harmonics.

What is considered here is mixed (Dirichlet-Neumann) boundary-value problem formulated as follows: the given pressure between baffles models the wave-beam generation, and the pressure exerted by the incident and scattered waves on the acoustically hard baffles models the response signal from the individual piezoelectric element of the array transducer. Efficient tools for rigorous solution of the above-mentioned problems can be delivered by the methods worked out earlier in electrostatics of planar systems of strips. These methods are further investigated and developed in this study for application in acoustic beam-forming analysis.

Electrostatic analysis of planar systems of perfectly conducting strips may explain fundamental features of microwave and micro-acoustic devices. It also provides the approximated solution to diffraction problems in along-wavelength limit. In this case the induced electric charge distributionon strips varies according to the incident electric field. In classical electrostatics, the boundary value problem is formulated for electric field or its potential governed by the Laplace equation appended by the boundary conditions on the system of strips. The solution provides the electric field in the space around strips and the electric induction (the electriccharge density) distribution on their surface.

Another approach exploits the theory of complex functions. Both these methods, however, are not applicable for the acoustic beam-forming analysis considered in this study. Here, instead, another approach is presented - the spectral theory. This is a different method for direct evaluation of the spatial spectrum of the charge distribution on planar system of strips. The charge spatial distribution itself can be obtained by the inverse Fourier transformation if needed. In many applications, like extensions of the electrostatic methods for the acoustic beam-forming analysis which are studied here, the spatial spectrum of charge distribution is the quantity of invaluable importance (e.g. for modeling of the frequency response of SAW transducers, beam pattern of acoustic transducers etc.).

In the case of planar system of periodic strips having arbitrary potentials or charge distributions, the spectrum can be obtained using the so-called generalized 'BIS-expansion' method. The approach exploits certain properties of the series of Legendre polynomials in order to satisfy the boundary condition in the consider boundary-value problem. The method was first introduced by **B**lotekjær, **I**ngebrigtsen, and **S**keie and was referred to as the BIS-expansion method. The detailed discussion concerning the BIS-expansion method and its generalization will be presented in details further in the Chapter 2. The method was also successfully used in the theory of electromagnetic wave scattering by planar systems of periodic conducting strips, in the theory of elastic wave scattering by periodic cracks, and in generalized form in the theory of surface acoustic wave transducers.

A

Tytuł załącznika A

Appendices (optional) can be added after the last section of the manuscript and before the references. Appendices should be numbered with capital letters.

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