Marek GARBARUK
Bialystok University of Technology, POLAND

Analysis of ultra-wideband linear antenna arrays

Abstract. *The article presents results of a computer simulation of ultrawideband (UWB) linear antenna arrays. UWB antenna arrays consisted of 2-5 elliptical radiators were considered. Different spacing between radiators was included in simulations. Characteristics of matching, frequency characteristics of antenna gain, antenna transmittances and shapes of an electric field radiated by the considered antenna arrays were shown and discussed in the article.*

Streszczenie. *W artykule przedstawione zostały wyniki komputerowej symulacji ultraszerokopasmowych (UWB) liniowych układów antenowych. Przeanalizowane zostały układy zawierające 2-5 eliptycznych promienników, rozmieszczonych w różnych odległościach. Przedstawione zostały charakterystyki dopasowania, zysku energetycznego oraz omówione promieniowanie sygnałów UWB. (**Analiza ultraszerokopasmowych liniowych szyków antenowych**).*

Keywords: UWB antennas, UWB antenna arrays, radiation of UWB signals.
Słowa kluczowe: ultraszerokopasmowe anteny, ultraszerokopasmowe układy antenowe, promieniowanie sygnałów UWB.

Introduction

Designing of UWB antennas has been a subject of a great interest in the recent years. There is a huge number of UWB single antenna constructions described in literature [1-2]. Broadly speaking, these antennas are characterized by almost omnidirectional radiation patterns and have a moderate gain. When a directional radiation pattern or higher value of antenna gain is needed, UWB arrays can be considered to be utilized in radio systems [3-6].

This article presents results of a computer analysis of linear UWB antenna arrays consisted of elliptical-shaped radiators. The analysis was performed in 6-8.5GHz European UWB band. The antennas of a similar structure have been presented in the earlier works of the author of the paper [7-9]. There are two approaches of how to analyze UWB arrays examined in the work: the analysis of antenna arrays radiation as well as radiation of UWB pulses emitted by antennas. Both of them are essential for estimation of EMD properties of UWB antennas.

Computer models of antennas

A basic structure of a single antenna, designed for 6-8.5GHz European UWB band is shown in Fig.1,a (dimensions in mm). An elliptical-shaped radiator is excited through a two-step stripline. It is connected to a middle wire of the excitation line and it is placed between two layers of a dielectric with a thickness of 1.575mm each, ε_r=2.2. The length of metallizations planes is H=0.56mm shorter than the length of a feeding line L (Fig.1,b). The width of metallization planes is by 10mm wider than the horizontal axis of the radiator. The advantage of a stripline is a shielding the excitation line from both sides, which reduces the impact of the feeding line on the characteristics and so it reduces disturbances to nearest devices. This is more noticeable in the analysis of arrays with an excitation networks.

UWB antenna arrays that are examined in the paper consist of a duplicate structures of the single antenna, placed next to each other and include N=2-5 radiators. An example of a 4-element UWB antenna array is shown in Fig.1,b. Ports are numbered consecutively from 1 to N. In each case, the front and back metallization extends beyond the outer edges of the external radiators by 5mm. Two values of the distance between the radiators D were considered: 5 and 10mm.

Results of a computer simulation of UWB arrays

All computations were made by means of commercial software IE3D. Frequency characteristics of SWR of a single antenna ($SWR_{s.a.}$) with SWR of a 4-element array are shown in Fig.2,a. There is a quite significant change of values of SWR for different ports of array due to a mutual coupling between radiators. Examples of radiation patterns cross sections are shown in Fig.2,b,c. Fig.3,a,b show the maximum gain (G_{max}) and the gain calculated in the direction perpendicular to the surface of antennas ($G_{\theta=90^\circ\varphi=0^\circ}$) of a 3- and 5-element array. The direction of a maximum radiation is in the x-z plane, a few degrees below direction perpendicular to the surface of all arrays.

For all analyzed UWB antenna arrays characteristics of antenna transmittance functions T_A were calculated [7,8], an example is presented in Fig.3,c. This transmittance simplifies the calculation of pulse shapes of an electric field emitted by the arrays. Fig.4,a shows example of pulse shape of an electric field radiated by a 4-element UWB antenna array in direction perpendicular to antenna surface. An in-phase excitation and Pulse Position Modulation was used in this case. The amplitude of excitation wavelets was 1V; parameters of pulses correspond to ETSI European regulations. The amplitude of an electric field radiated by the analyzed antenna array is referred to a distance of 1m from the antenna.

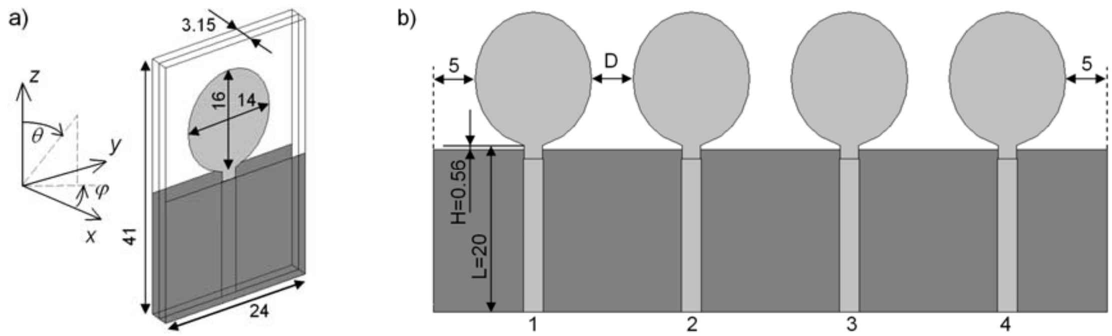

Fig.1. The structure of a basic single UWB antenna (a) and the example of a 4-element UWB antenna array (b) (dimensions in mm)

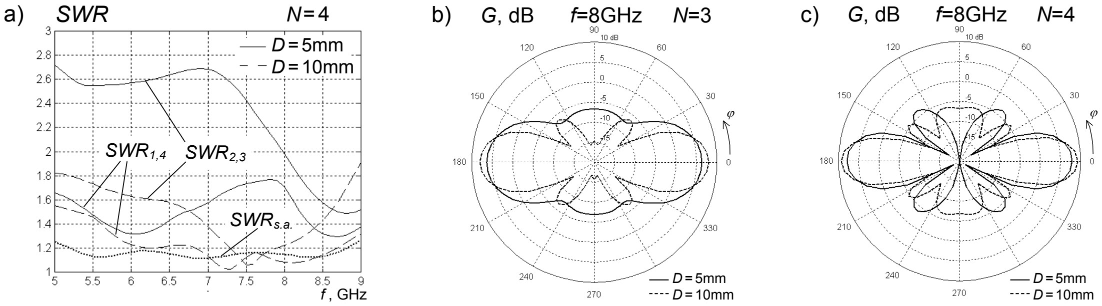

Fig.2. *SWR* (a) and radiation patterns (b,c) of selected models of antennas

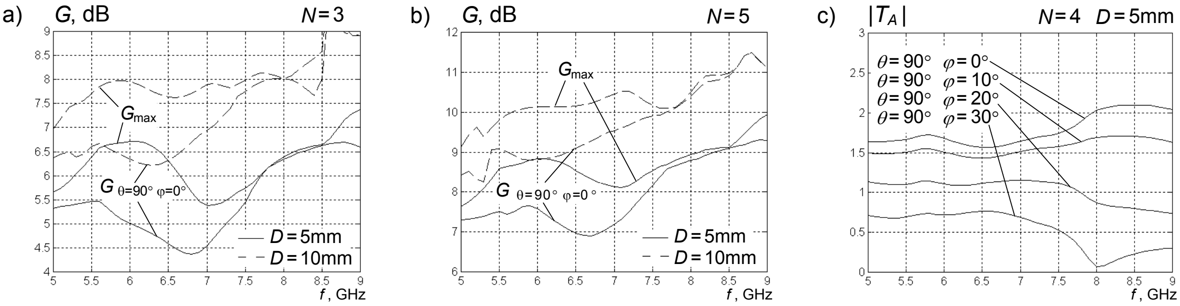

Fig.3. Antenna gain for different arrays (a,b) and modules of a 4-element antenna array transmittance for different directions

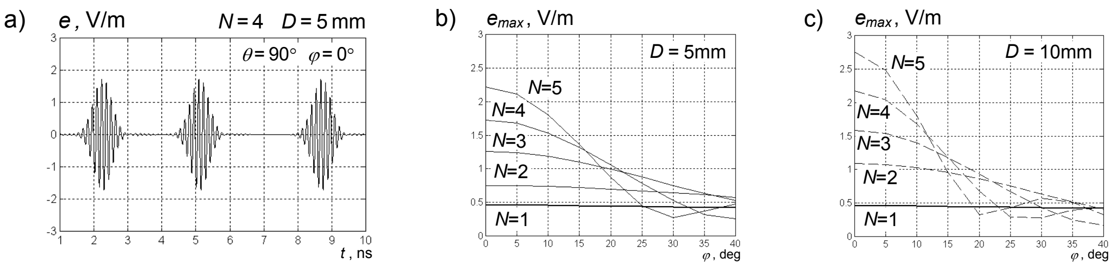

Fig.4. Pulse shapes of an electric field radiated by a 4-element UWB antenna array and amplitudes of pulses radiated by a 4-element array in x-y plane for different directions (b,c)

Shapes of radiated pulses of an electric field are almost the same as the excitation, which is characteristic for UWB wallets. Amplitudes of electric field pulses for different variants of antenna arrays, radiated in different directions (marked as φ) in *x-y* plane were calculated and presented in Fig.4,b,c. Only the interval 0-40° was considered. A reference point is a characteristic for a single antenna (*N*=1), which is almost omnidirectional. As it might be expected, amplitudes of pulses rise with the increase of distance *D*, a number of radiators (and a number of generators and so a total input power), and decrease with the increase of φ angle.

Conclusions

Results of a computer simulation of linear ultra-wideband antenna arrays were presented in the paper. Characteristics of network parameters, radiation patterns, a gain and a transmittance of antennas and radiation of UWB pulses were considered. The analysis of properties of UWB antenna arrays should take into consideration not only basic radiation characteristics at chosen frequencies but also frequency characteristics of antenna transmittances and the analysis of pulses of an electric field radiated in different directions.

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***Author**: dr inż. Marek Garbaruk, Politechnika Białostocka, Wydział Elektryczny, Katedra Telekomunikacji i Aparatury Elektronicznej, ul. Wiejska 45D, 15-351 Białystok, E-mail: mgarbaruk@pb.edu.pl.*