VISUALISATION OF ELECTROMAGNETIC PHENOMENA USING AUGMENTED REALITY BASED ON THE EXAMPLE OF A HORN ANTENNA

Dawid Budnarowski[1]*, Jerzy Mizeraczyk[2], Magdalena Budnarowska[3]

[1,2,3] Gdynia Maritime University, 81-87 Morska St., 81-225 Gdynia, Poland,
Faculty of Electrical Engineering, Department of Marine Telecommunications[1], Department of Marine Electronics[2,3]

[1] ORCID: 0009-0005-1200-1793, e-mail:d.budnarowski@we.umg.edu.pl

[2] ORCID 0000-0002-5173-3592

[3] ORCID 0000-0002-5341-7585

* Corresponding author

Abstract: The paper presents and discusses the operation of a mobile application using the Augmented Reality (AR) to visualize the electromagnetic (EM) radiation of a horn antenna. The mobile application serves as a teaching aid and complements the laboratory setup for investigating EM radiation from a horn antenna. The EM radiation visualisation data were obtained through numerical simulation using the CST Studio Suite software, which enables modelling and simulation of various EM interactions. The mobile application was created using the Unity engine, which enables the development of mobile applications. The Vuforia library was used to implement digital data (obtained through numerical simulation) and overlay it onto the real image captured by the mobile camera. The application runs on devices with Android 8.0 and higher, and integrates the real 3D environment with virtual reality in real time.

Keywords: mobile application, Augmented Reality, AR, visualisation of electromagnetic phenomena, horn antennas.

1. INTRODUCTION

Augmented Reality (AR) is a field of computer science that deals with combining elements created using computer technology (2D and 3D models, video films, images, etc.), with images of the real world. Unlike Virtual Reality (VR), AR does not create a complete 3D virtual world, but instead adds additional content to the 3D real world [Hsin-Kai et al. 2013].

The beginning of AR research dates back to the 1960s, when Ivan Sutherland constructed a device called The Sword of Damocles. It is considered the first Head-Mounted Display (HMD) for augmented reality. The device displayed output data

from a computer program on a stereoscopic display and enabled head movement tracking [Chen et al. 2019].

The term "Augmented Reality" was first used by Boeing employee Tom Caudell in 1990. In 1996, Jan Rekimoto constructed a device called NaviCam, which enabled the integration of real-world environments and digitally generated objects in real-time using two-dimensional markers [Heilig 1962; Rekimoto and Nagao 1995; Azuma 1997; Packer 1999; Pardel 2009].

In 1997, Ronald Azuma introduced the definition of augmented reality, which describes AR as a system that [Azuma 1997; Delello 2014]:

- integrates real and virtual environments;
- is interactive in real-time;
- operates in 3D space.

Further development of augmented reality has resulted from the growing capabilities of mobile devices.

AR is used in medicine for visualisation and training before procedures. Non-invasive diagnostics using techniques such as magnetic resonance imaging, computed tomography or ultrasound imaging provide extensive real-time patient data, and AR enables their integration with what the doctor sees [Durlach and Mavor 1995; Kancherla et al. 1995; Eckert, Volmerg and Friedrich 2019]. In industry, AR is used, amongst other things, in conservation work and repairs of complex equipment and systems. AR-based instructions are much more accessible and easier to use. Descriptions, drawings, and instructional videos overlaid on individual elements of real equipment help to perform tasks step-by-step in an easier and faster way without the need for heavy, easily damaged paper instructions [Mihran et al. 1995; Sims 1995; Gattullo et al. 2019].

AR also works well in many areas of life for displaying data and visualisation. One good example is displaying information about the content of library shelves during a visit to the library [Fitzmaurice 1993; Greene and Groenendyk 2021] or viewing the interior of a house for sale without the need to schedule appointments with intermediaries [Caudell and Mizell 1992].

In the entertainment industry, AR technology is used in games to enhance gameplay between players. The possibility of expanding gameplay in the game through an AR application update, without the need for players to buy add-ons and incur additional costs, is a very attractive option for potential customers. In recent years, AR technology has also been gaining popularity in the field of education. The reason for this is the rapidly increasing number of mobile devices enabling easy access to AR applications. This technology is an excellent addition to educational activities, thanks to the possibility of visualising phenomena and processes not visible to the naked eye as well as observing dangerous experiments in Augmented Reality [*Invizimals*... 2023].

This paper presents the operation of a mobile application using augmented reality to visualise the electromagnetic (EM) radiation of a horn antenna.

The application runs on Android devices and integrates the real environment and virtual reality in real time, in a 3D space. The application complements the laboratory setup for studying horn antennas and serves as an attractive educational aid for visualising EM radiation.

2. SIMULATED PROCEDURE OF THE EM RADIATION OF A HORN ANTENNA

The CST Studio Suite is a software program that enables the modelling and simulation of the electromagnetic (EM) interaction between electromagnetic radiation and designed objects. With the CST Studio Suite, it is possible to design, simulate, analyse and optimise both single material elements and complex electronic devices across a broad range of frequencies [CST Studio Suite 2023].

The CST Studio environment was used to model the electromagnetic radiation emitted by a horn antenna.

The geometric diagram of the tested horn antenna is shown in Figure 1. The antenna is placed in a rectangular coordinate system. The external dimensions of the tested antenna, which correspond to the real dimensions of the horn antenna, are: W = 140.36 mm (x (-70.18 mm, +70.18 mm)), H = 102.08 mm (y (-51.04 mm, +51.04 mm)), D = 201.09 mm (z (-1 mm, +173 mm)). The wall thickness is 1 mm. For simulation purposes, the antenna in the CST program is made of a material with infinite conductivity, PEC (Perfect Electric Conductor). The frequency range of the tested antenna is 8–12.4 GHz.
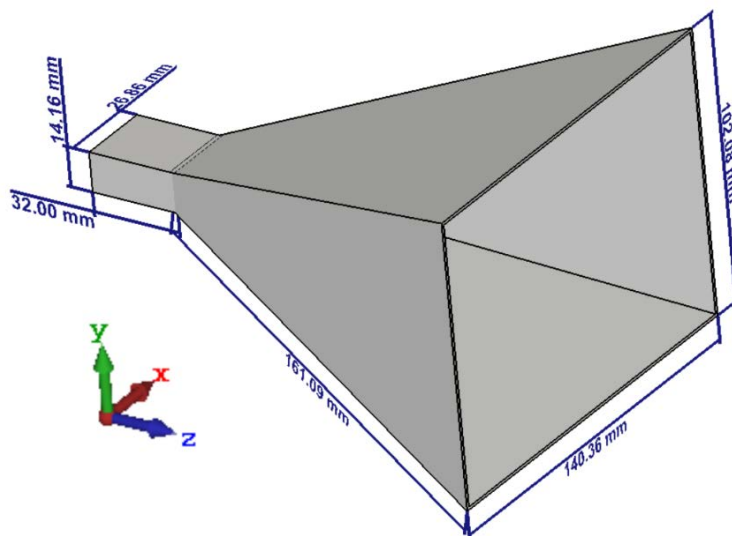

Fig. 1. A geometric diagram of the horn antenna

The computational domain of the CST program is shown in Figure 2. This area has been chosen to enable the visualisation of EM radiation in three planes around the tested antenna. The dimensions of this area are 270.18 mm in the x-axis, 126 mm in the y-axis and 850 mm in the z-axis.
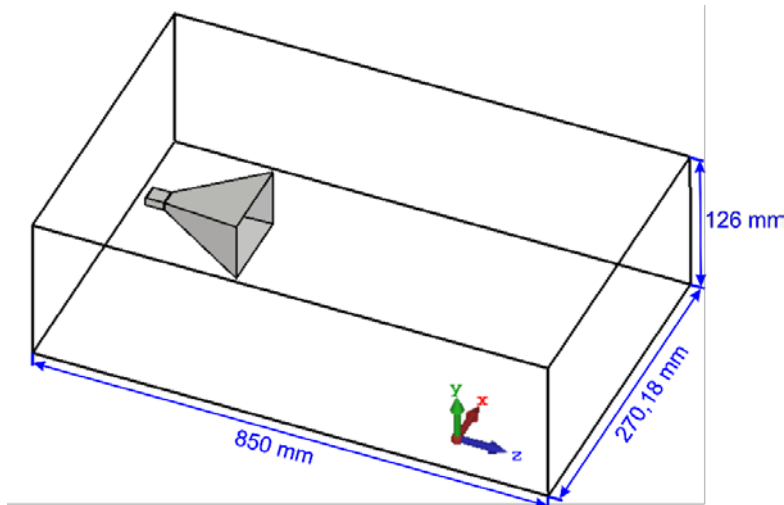

Fig. 2. The computational area of the CST Studio Suite software around the horn antenna tested

3. MOBILE APLICATION

The application aims to visualise the EM radiation emitted by the horn antenna using AR. The operation of the application involves recognising and tracking a graphic marker placed on the real horn antenna in the camera image and overlaying the EM radiation 3D model with video material on the camera image. After installing the application on a mobile device, the user directs the camera at the marker, and the application overlays the EM radiation 3D model on the camera image in AR.

3.1. Numerical data

The input data for preparing an animation overlaying the camera image were obtained from numerical simulations conducted in the CST Studio Suite software. These data include the development of the electric and magnetic fields in the space around the horn antenna. The resulting animation shows the development of the electric field in the $x = 0$ plane and the magnetic field in the $y = 0$ plane over a period of 5 nanoseconds. The duration of the animation is 4 minutes and 22 seconds

(262 frames of animation at a speed of 1 frame per second) and it was prepared in mp4 format supported in the Unity environment.

3.2. Marker

The role of the marker is to trigger a specific action in the application. In the case of the written application, this action is to load videos, overlay them on the camera image in real time and then place them in the appropriate location specified by the marker.

The graphic selected for recognition by the mobile camera is shown in Figure 3.

Fig. 3. The marker used in the application

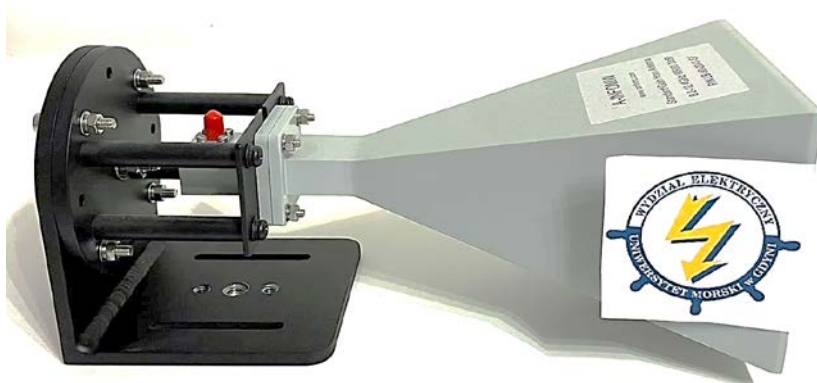The marker was placed on the real horn antenna (Fig. 4).

Fig. 4. The real horn antenna with the marker

3.3. Graphical user interface of the application

The main screen of the application has a graphical user interface consisting of buttons for turning on/off the YZ and XY planes of the EM radiation emitted by the horn antenna, a text message informing the user to point the camera at the marker and a message about the actual length of the video material. The actual length of the simulation of the phenomenon is 5 nanoseconds, while the duration of the animation is 4 minutes and 22 seconds.

The operation of the application and visualisation of electromagnetic radiation around the horn antenna using AR are shown in Figure 5.
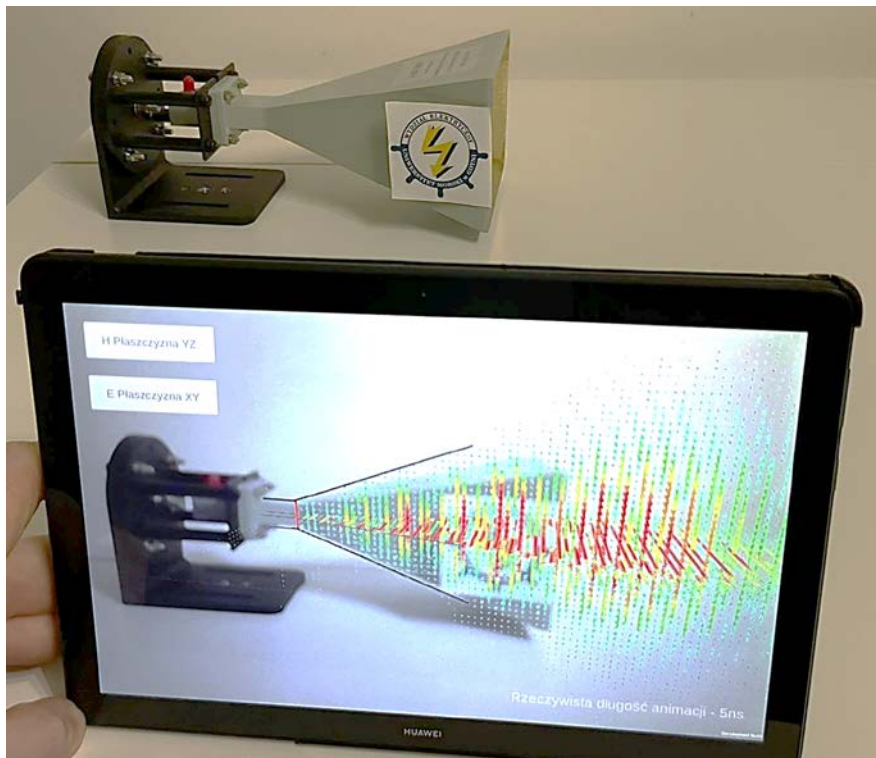
Fig. 5. Illustration of the operation of the application and visualisation of the electromagnetic radiation emitted by the horn antenna

4. CONCLUSIONS

The article presents a mobile application for visualisation of EM phenomena using Augmented Reality (AR) based on the example of the operation of a horn antenna.

The application developed has educational value and enables a better understanding of physical phenomena.

The Augmented Reality application described in this communication has enabled the observation of electromagnetic phenomena invisible to the naked eye and a better understanding of the propagation mechanism of electromagnetic radiation emitted by the horn antenna into free space.

The Augmented Reality application was experimentally tested to visually determine the range of the electromagnetic radiation emitted by the horn antenna in the space of the Laboratory of Microwave Technology at the Gdynia Maritime University.

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