Aspects of Modelling a UWB Impulse Radiating Antenna

***Holger Thye*[1], *Michael Koch*[1], *Frank Sabath*[2]**

[1]Leibniz University Hannover, Institute of the Basics of Electrical Engineering and Measurement Science, Appelstr. 9A, 30167 Hannover, Germany, Email: thye@ieee.org

[2]Armed Forces Scientific Institute for Protection Technologies (WIS), Munster , Germany

Abstract

For military applications it is of interest to affect distant targets with short electromagnetic pulses of high amplitude and a broad spectral content from 100 MHz to several GHz which are known as Ultra Wide Band Pulses (UWB). The standard Impulse Radiating Antenna (IRA) is a reflector type antenna with a high directivity. A modified, collapsible textile IRA which can be integrated in a standard parachute was developed as part of a project initiated by the German Armed Forces Institute for Protection Technologies (WIS) in 2001. Measurements have shown that the maximum amplitude of the radiated field is limited by the design of the feeding section. Different commercially available simulation tools were used to build models of the feeding section in order to optimize the geometry. The aim is to minimize reflections and maximize amplitude of the voltage pulse which can be transmitted without leading to breakthrough effects . This contribution deals with aspects of the modelling process and presents first results.

1. Introduction

Electronic components and subsystems (e.g. microprocessor boards) are essential parts of modern civilian and military systems. A setup or failure in these systems could cause a major accident. Due to the impact of electromagnetic fields on the functionality of electronic components, microwave applications are of large interest for the development of non lethal weapons. The capabilities of High Power Microwaves (HPM) and UWB weapons are the reason for intensive research activities in the area of microwave sources, components and antennas. UWB-sources with an output voltage of several MV are published in open literature [1,2].

For military applications it is of interest to affect distant targets with HPM or UWB type fields. The maximum amplitude of the electrical field strength at the target is limited by two factors:

1. The maximum voltage amplitude which can be applied to the textile antenna. Since sources with output voltages as high as 700 KV are available the maximum amplitude is not limited by the source but by the dielectric strength of air. The critical part of the antenna is the feeding section, where the distance between the conductors is relatively small.

2. The distance between the antenna and the target at the moment the impulse is radiated. Since the amplitude of the electrical field decreases proportional to $1/r$, the distance between the microwave antenna and the chosen target should be as small as possible. The necessary range for several military applications can only be achieved by using carrier systems.

The standard Impulse Radiating Antenna (IRA) is a reflector type antenna with the ability to radiate broadband pulses with a high directivity. In a joint research project which has been started in 2001 between the German armed forces, the company Autoflug GmbH in Rellingen, Germany, and the Leibniz University of Hannover, Germany, the technological possibilities and limits of parabolic ultra wideband IRAs made of conductive textile and integrated into a parachute are examined. For effectively influencing electronic equipment, these antennas have to radiate high amplitude electromagnetic pulses with rising times far below a nanoscecond. In order to do so, the first aspects of the research were the construction of the feeding section, the reflector and the development of the textile resistors. The resulting design and first measurements were presented in 2004 and 2006 [3,4]. The main question emerging from these tests was the optimal design of the high voltage feeding section.

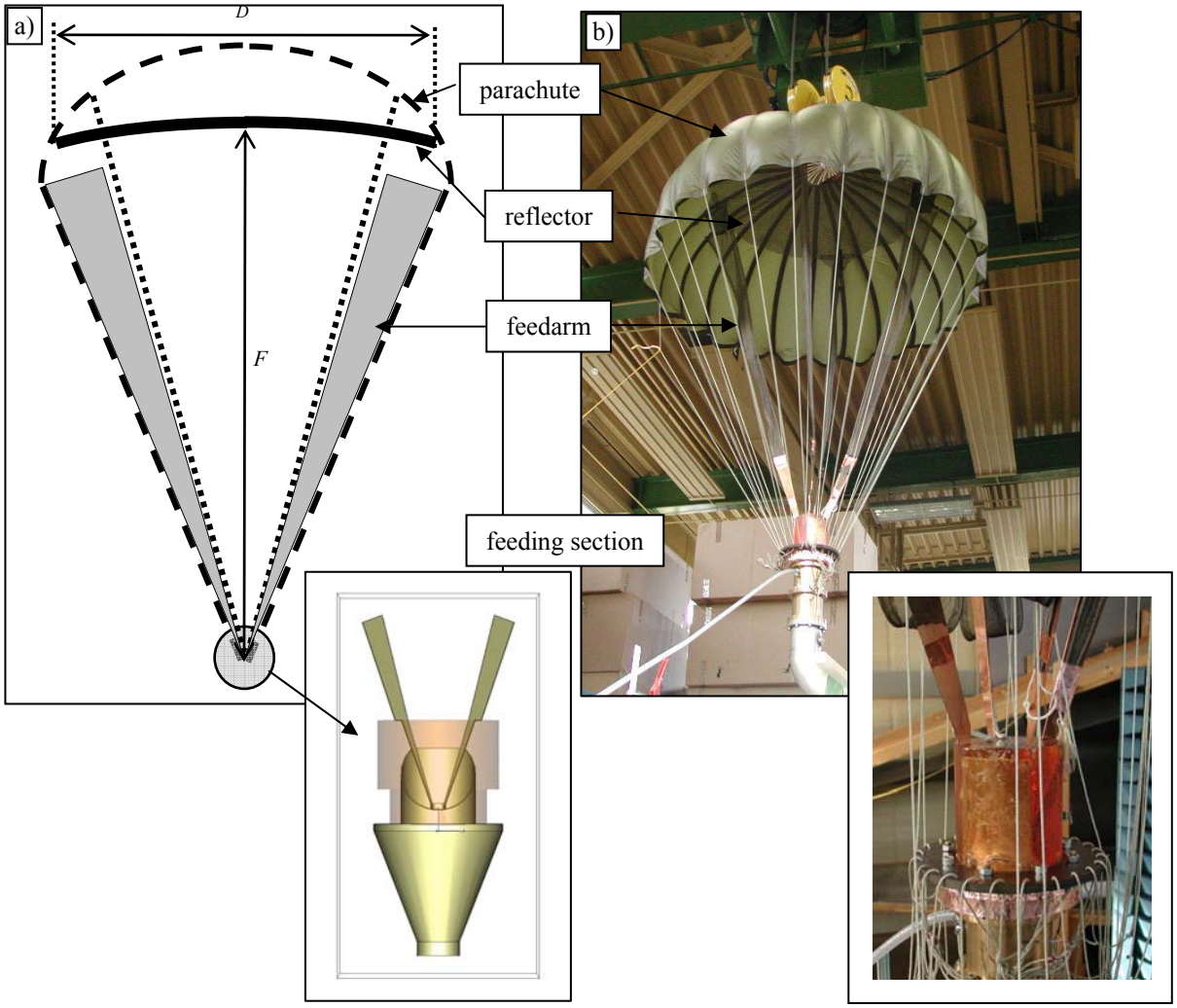

Fig. 1: IRA antenna with the focus on the feeding section; a) draft, b) reality

Therefore, this contribution focusses on the feeding section of the antenna. In order to prevent a breakdown between the feedarms at the excitation point of the IRA, the feeding section is surrounded by epoxy resin molding material. This material has a relative permittivity ε_r of about 4. Fig. 1 shows a draft and a photograph of the IRA with the parachute, the reflector and the feedarms. The reflector and the connection between the reflector and the metallic feedarms is made of conductive textiles. The reflector has a diameter D of about 1.6 m, and the distance F between the feeding section and the reflector is 1.6 m.

In the following sections some major aspects of modelling the feeding section will be described in order to get an impression of the implementation in the used simulation tools. The simulation tools are the commercial available software COMSOL Multiphysics, which uses the Finite Elemente Method (FEM) and CST Microwave Studio (CST MWS), which uses the Finite Integration Technique (FIT). Both methods are based on volume discretization. In both software tools the geometric dimensions of the section consisting of conductive material and the epoxy resin are implemented. The two important points (volumes in the feeding section with possible breakdowns and the field propagation inside the feeding section) are analyzed. In the conclusion the advantages and disadvantages of each numerical method will be analyzed according to the results.

2. FEM Simulation

It is proven, that the breakdown voltage value between two conductors increases by using a transient voltage signal [5]. Further, this effect intensifies with pulses getting shorter, because it needs time to build a streamer

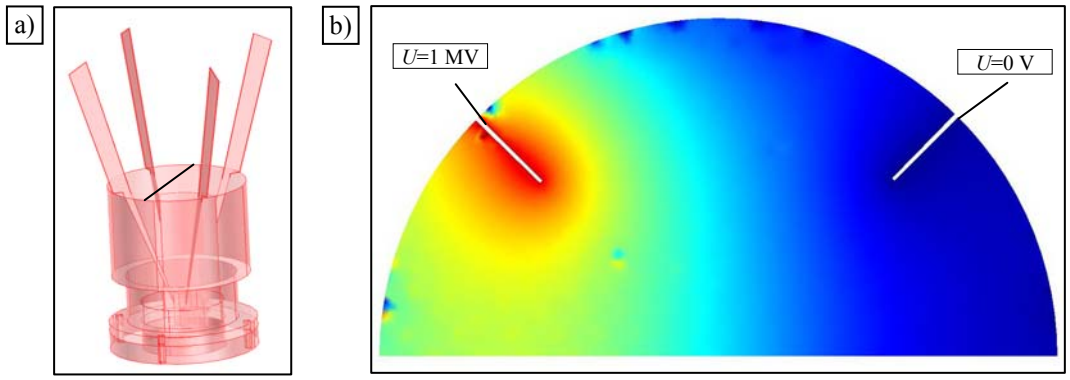

Fig. 1:a) FEM-model of the IRA-feeding section, b) calculated voltage on the surface of the epoxy resin

channel between the conductors for the discharge. In order to get an impression of the field strength inside the feeding section and the volume where a breakdown can happen, the electrostatic module of COMSOL is used to apply a static voltage excitation on the conductors. A resulting electrostatic field can be calculated and gives a worst case estimation as a basis for geometric optimization. Fig 2a shows the FEM-simulation model of the feeding section built with the drawing mode in COMSOL. Fig 2b shows the calculated voltage on the surface of the epoxy resin.

3. FIT Simulation

The FIT simulation model was created to simulate the electric field propagation inside the feeding section. In the used simulation tool CST MWS it is possible to calculate both the time dependent voltage signal between two arbitrary points and the time dependent electromagnetic field in selected planes in the model. The wave impedance can be calculated according to the geometry and the excitation port. Here, the port is a coaxial port with the inner radius r and the outer radius R. In order to get the best match to the 50-Ohm-impedance of the voltage source , the first step is to define the radii according to Eq. 1 [6].

$$Z_L = \frac{60\,\Omega}{\sqrt{\varepsilon_r}} \ln \frac{R}{r} \tag{1}$$

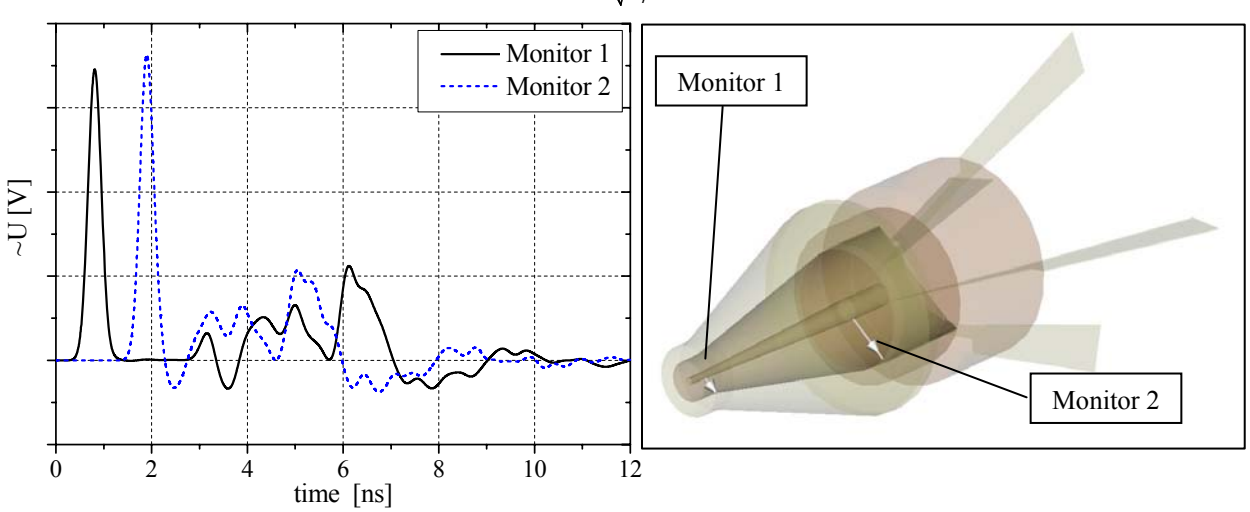

Fig. 2: FIT-Simulation results (voltage signals at two monitors inside of the feeding section)

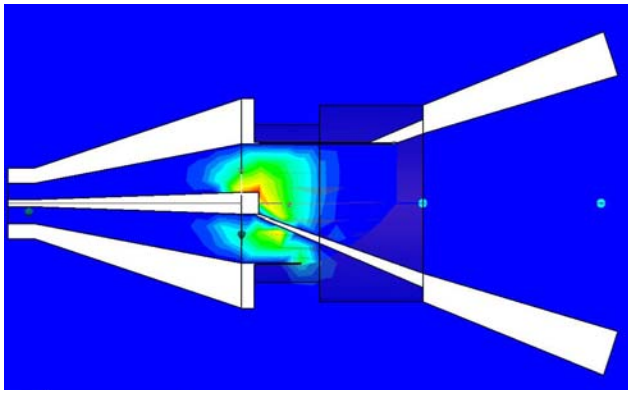

Fig. 3: Simulation results in a cross section of the APEX (magnitude of the electric field 2.1 ns after excitation)

The pulse shape of the exciting TEM mode signal can be changed and individually specified. The default excitation time signal in CST MWS consists of a Gaussian Pulse. The simulation results in time domain are separated in voltage signals and 3D-field strengths. Fig. 3 shows two defined voltage monitors and the calculated signals. Monitor 1 is placed near the port, monitor 2 at the end of the cone shaped coaxial adapter. The main pulse can be identified with its maximum at t_{V1} = 0.8 ns at monitor 1 and t_{V2} =1.9 ns at monitor 2. Some reflections resulting from the transition between coaxial conductor and feedarm can be seen shortly after in reverse order. The time dependent field distribution at this transition can be analyzed in a cross section parallel to the direction of wave propagation. Fig. 4 shows the electric field 2.1 ns after excitation. As expected, there is an increase of the electric field strength at the transition of the inner conductor to the plus feedarms. This is a indication of a strong unwanted reflection at this point. By dint of the electric field calculation the geometry of this transistion can be changed to minimze the reflection.

4. Conclusion

In this contribution the simulation of the IRA-feeding section was presented. It was shown that the electromagnetic module of a FEM simulation can be made as a worst case estimation for definition of the volume, in which a breakdown between the conductors can happen. The numerical calculation in time domain has the advantage to show the 3D-wave propagation and to detect the reflections of the excitation pulse. The results are the basis of a parameter study to get a geometric optimization of the model. The next step is to build the optimized geometries in reality and test the device.

References

1. D.V: Giri: “High Power Electro-Magnetic Radiators", Harvard University Press, 2004

2. C.D. Taylor and D.V. Giri: "High Power Microwave Systems", Taylor and Francis, 1994

3. H. Herlemann, M. Koch, F. Sabath: "UWB-Antenna for Artillery Applications", BoA, EUROEM 2004

4. H. Herlemann, T. Stadtler, M. Koch, J.T. ter Haseborg: "Near-Field Scanning of UWB-Antenna-Footprint in Time Domain", EMC Europe, Barcelona, Spain, September 2006, pp.1024-1029

5. Y.D. Korolev, G.A. Mesyats: "Physics of Pulsed Breakdown in Gases", Yekaterinburg, URO-Press, 1998

6. O. Zinke, H. Brunswick: "Lehrbuch der Hochfrequenztechnik", Springer Verlag, 1973