HPEM AGAINST ELECTRONIC SYSTEMS[1]

Markus Jung, Gerd Wollmann

Rheinmetall Waffe Munition GmbH,
Branch Unterluess, Heinrich-Ehrhardt-Strasse 2, G-29345 Unterluess

Abstract

Modern military and commercial systems are increasingly relying on electronics, sensors and networks. High Power Electromagnetic (HPEM) seems to be a promising non lethal weapon to disturb the electronic systems. This could lead to a fire power, mission or even catastrophic kill.

The paper describes basics of the HPEM technology. It covers differences between narrowband (HPM), ultra wideband (UWB) and damped sinusoidal (DS)[2] waveforms in the time and frequency domains. Requirements for front door and back door coupling into electronic equipment are formulated.

After an overview of the technology of UWB sources including antennas, typical scenarios for HPEM based non lethal weapons are discussed. Different effects caused by HPEM sources are explained.

The contribution ends with a description of autonomous HPEM systems and their future capabilities for further applications as non lethal weapons.

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[1] At the end of 2002, Rheinmetall Waffe Munition GmbH and Diehl BGT Defence GmbH & Co KG signed a cooperation agreement on the exclusive worldwide cooperation with the objective of a common conceptual design, development, production, marketing and maintenance of HPM Sources and HPM Systems.

[2] See also: Compact High-Power RF Sources for Non-Lethal Applications, 2nd European Symposium on Non Lethal Weapons, 2003

I. Introduction

During the last decade the operation spectrum of the NATO armed forces has changed from home land defense to mainly peace keeping missions. The protection of convoys and military bases against asymmetric threats like car bomb, improvised explosive devices (IEDs) low cost UAVs or remote controlled bombs have become high priorities. For some of the asymmetric threats, conventional weapons are not available or can not be used because of their lethal effects.

II. Waveforms in time and frequency domain

Classical HPM generators as Magnetron, BWO, Klystrons produce an output signal at fixed frequencies for a time between 10 – 100 ns. In Figure 1 the time behavior of a typical HPM pulse with a center frequency of 500 MHz and a pulse length of 40 ns is shown.

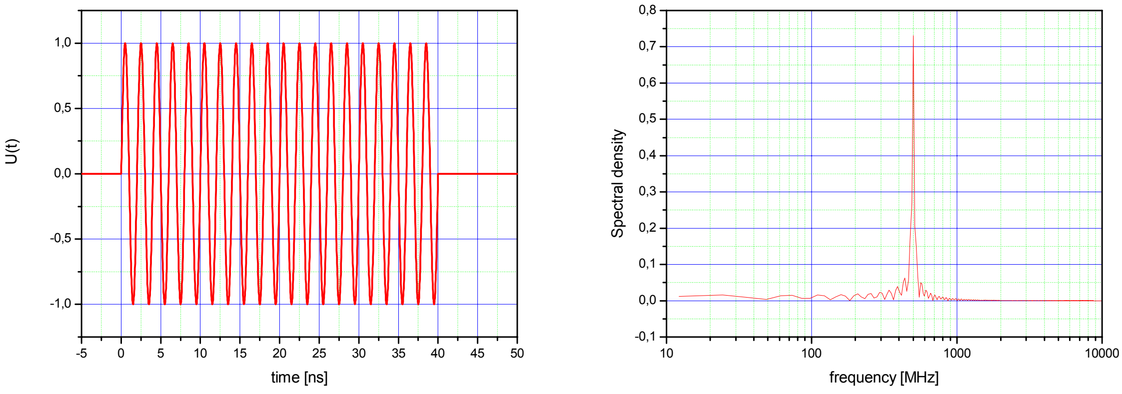

Figure 1 Time Frequency behavior of the continuous wave signal

By transforming the waveform of the HPM pulse from the time into the frequency domain we receive a sharp line at the center frequency of 500 MHz. This means, that most of the energy is concentrated in a small frequency area. The width of the distribution in the frequency domain depends on the pulse length, the Q-factor of the resonator etc.

The waveform of an Ultra Wideband Pulser is very short, with rise times below 500 ps (see Figure 2). By transferring this short pulse from the time domain region into the frequency domain region the pulse energy is distributed over a wide spectrum area, therefore the spectral energy density is low. This can be compensated by higher repetition rates.
In real systems, the emitted lower frequency depends on the dimensions of the antenna. The upper frequency is limited by the risetime of the pulse. With a rise time below 200 ps an upper frequency limit of about 2 GHz is reached.

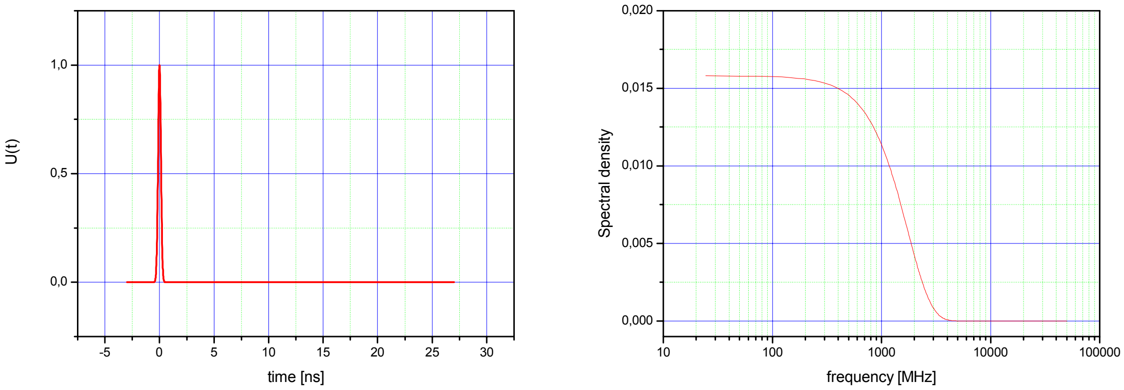

Figure 2 Time and Frequency domain behaviour of the UWB Pulse signal

Between the two extreme waveforms of CW and UWB there is the Damped Sinusoidal Wave, which is shown in Figure 3; it consists of a short pulse risetime and a declining ring for several nanoseconds. Most of the energy is concentrated at the center frequency, but the bandwidth is much wider compared to the spectral distribution of the CW wave form.

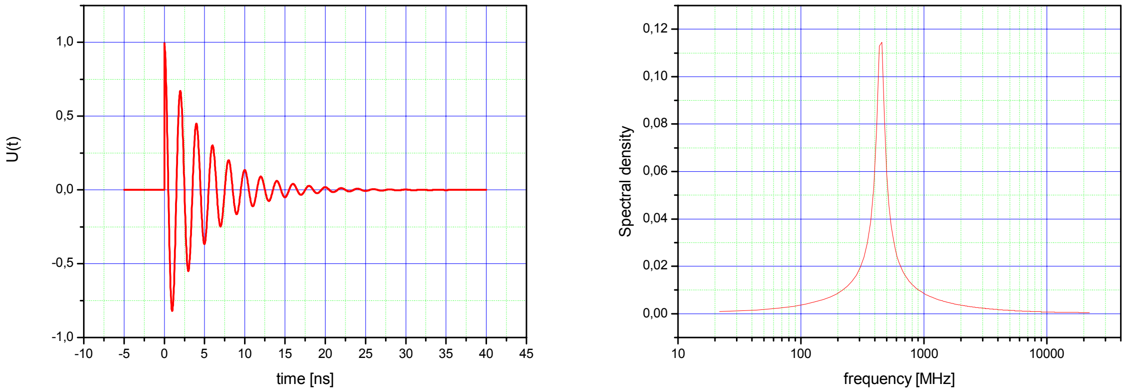

Figure 3 Time and Frequency domain behaviour of the DS signal

III. Coupling effects

The coupling of electromagnetic energy into an electronic target is divided into two main areas “Front Door Coupling” and “Back Door Coupling”.

Front Door Coupling

In the case of Front Door coupling the electromagnetic wave is coupling over the receiving antennas into the target directly. Therefore the electromagnetic wave must have the right frequency to come over the receiving channel into the system.

Back Door Coupling

In the case of Back Door Coupling the electromagnetic wave is coupling over slits, openings and feed through into the target. The coupling behavior of a target could be split into 3 main areas, the differential area, the resonance area and the integration area (see Figure 4).

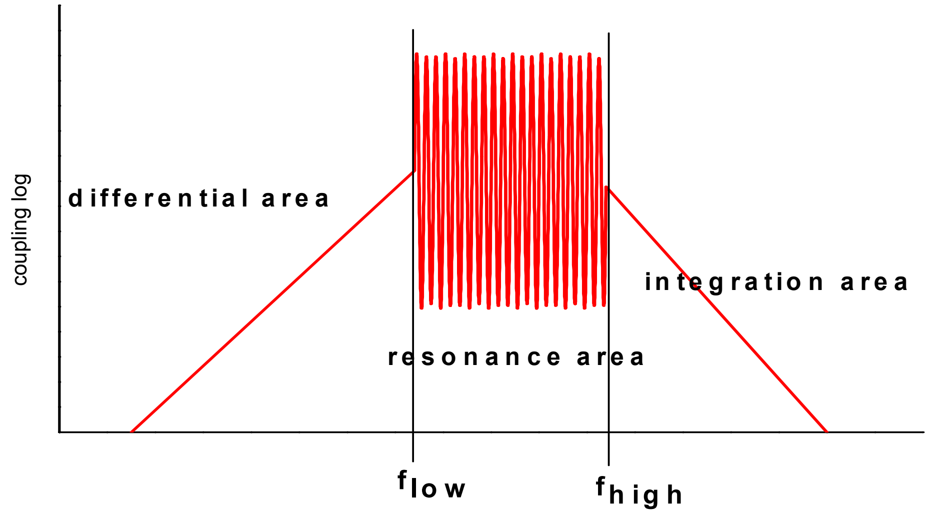

Figure 4 Back Door Coupling areas

The resonance area is limited by the lower frequency which could be estimated from the maximum dimensions of the target to be equal to a λ/2 of an antenna. The upper limit is given by the smallest dimension of the PCB-boards and is in the range of 3 GHz.

Electromagnetic effects

Depending on the energy which is coupled into the target the effects on the target are different. At the lowest level of energy density in the target the communication is suppressed, at higher energy levels the electronic circuit is neutralized starting from resetting the clock on integrated circuits to erasing the memory on EPROM chips. At the highest energy level parts of integrated circuits will be destroyed by overheating certain areas in the chip.

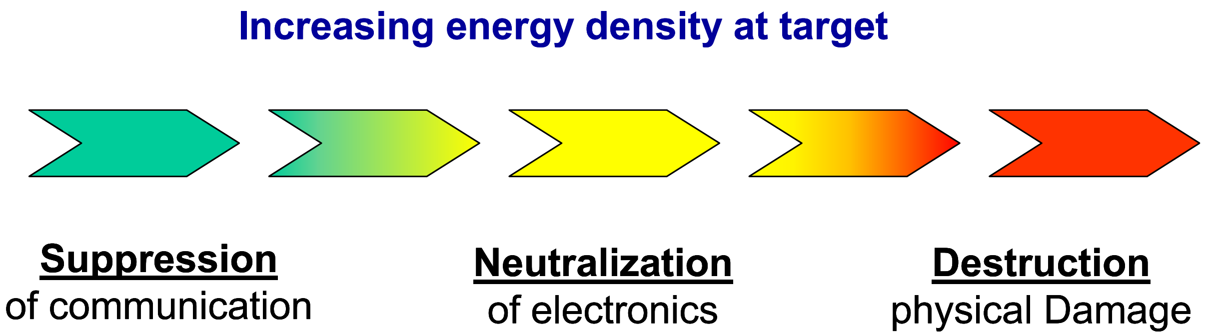

Figure 5 Effect levels with increasing energy density

IV. Ultra wideband source technology

An ultra wideband source consists of two main components, the sub-ns pulser and the antenna.

Pulser

Semiconductor based sub–ns pulser have made enormous progress in the last 10 years in respect of increasing output voltage, repetition rate and risetime reduction.

In Figure 6 the RHL350k, a compact sub-ns Pulser is shown. The pulser is able to produce from a 200 VDC input voltage a 4 kV output voltage with a risetime of about 150 ps. The maximum repetition rate is 10 kHz. The dimensions of the pulser are 40x40x120 mm.

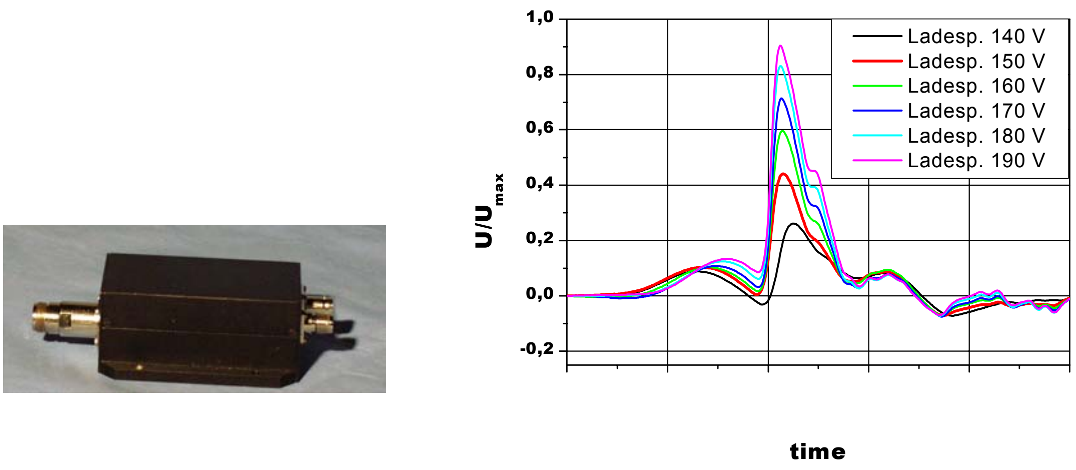

Figure 6 Sub-ns semiconductor pulserRHL350k and output voltage behavior

The technology development of sub-ns- pulser is divided into two main streams:

- increasing the output voltage above 200 kV at reduced repetition rates
- increasing the repetition rate above 100 kHz with output voltages below 10 kV

Comparing the semiconductor pulser with gas switched devices, the semiconductor pulsers are able to run at much higher repetition rate, but the maximum output voltage is below the capabilities of gas switched systems. Due to the high controllability of the semiconductor pulser it is possible to synchronize several pulsers with extremely short pulses in such a manner, that the emitted field pulse of the antenna of each pulser is positively superimposed in the field at great distance. In Figure 7 an antenna with inputs for 4 sub-ns pulser type RHL020M (30 kV, 1 kHz) is shown on the left side, on the right side is the normalized far field strength of the 4 pulsers. The risetime of the pulse is below 140 ps, so the synchronization is better than 20 ps. The increase of the risetime of the superimposed pulse compared to the risetime of a single pulse could not be measured with the scope at 20 Gs/s.

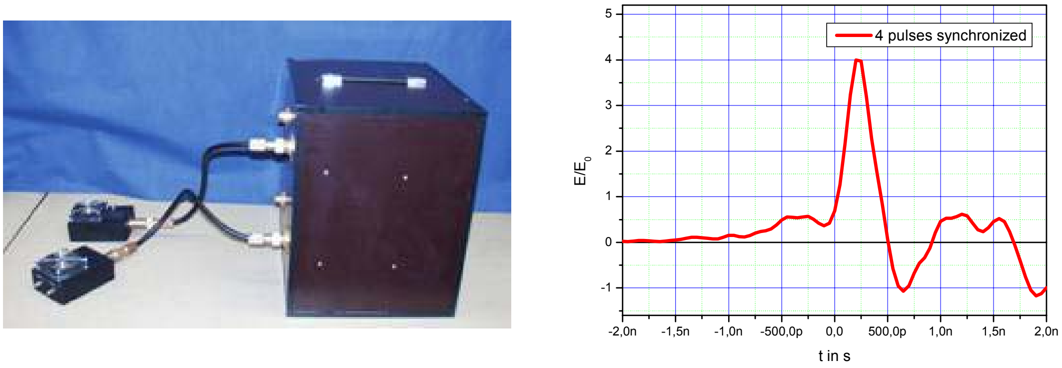

Figure 7 Synchronization of 4 RHL020M setup and measurement of the field at great distance

By using the asynchronous operation mode it is possible to generate different pulse series with fixed or variable time distances. This technology could be used to adapt the spectral distribution of the pulser to the known coupling resonances or clock rates of the target. The threshold for neutralization will be reduced.

Antennas for sub ns Pulser

To emit extremely short pulses, world wide several antenna configurations have been tested: Impulse Radiating Antennas, full and half IRAs, TEM horn antennas, Bow Ties etc. Standard wide band antennas like log periodic, spiral etc. are not suitable for the emitting of wide band pulses, due to their phase dispersion. The short pulse in the time domain will be transformed into a wide pulse at reduced amplitude.

In Figure 8 the basic module of a 2 x 2 horn array antenna is shown with the dimensions of 0,25 x 0,25 x 0,35 m, combining 16 of the basic modules to an antenna array with an aperture of 1,2 x 1,2 m, fwhm angle is about 15°.

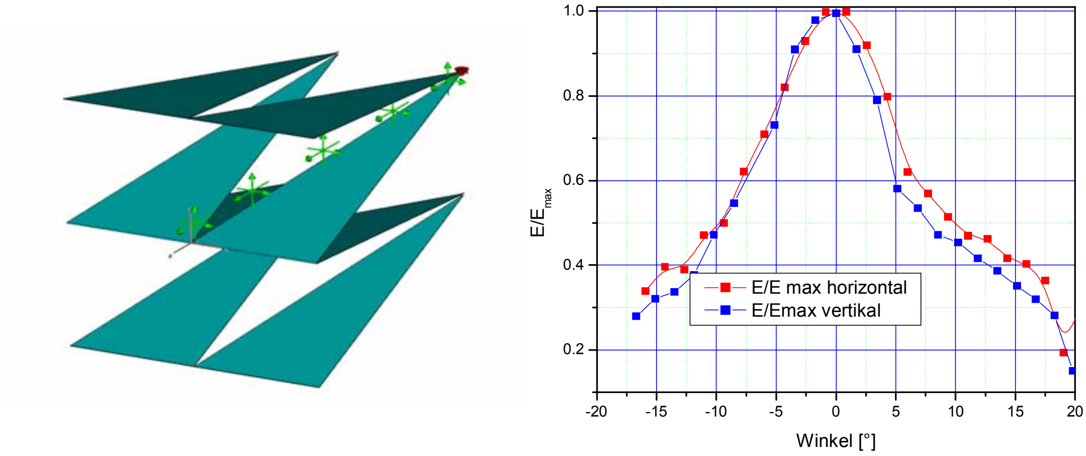

Figure 8 Basic TEM horn array module, field distribution of 1.2 x 1.2 m antenna array

For several applications an antenna depth of more than 20 cm is not acceptable. To fulfill these requirements the antenna design was changed from horn antennas to Bow Tie type antennas (Figure 9). The antenna depth is less than 100 mm, which is compensated by an fwhm angle of 30° and a reduced peak field strength.

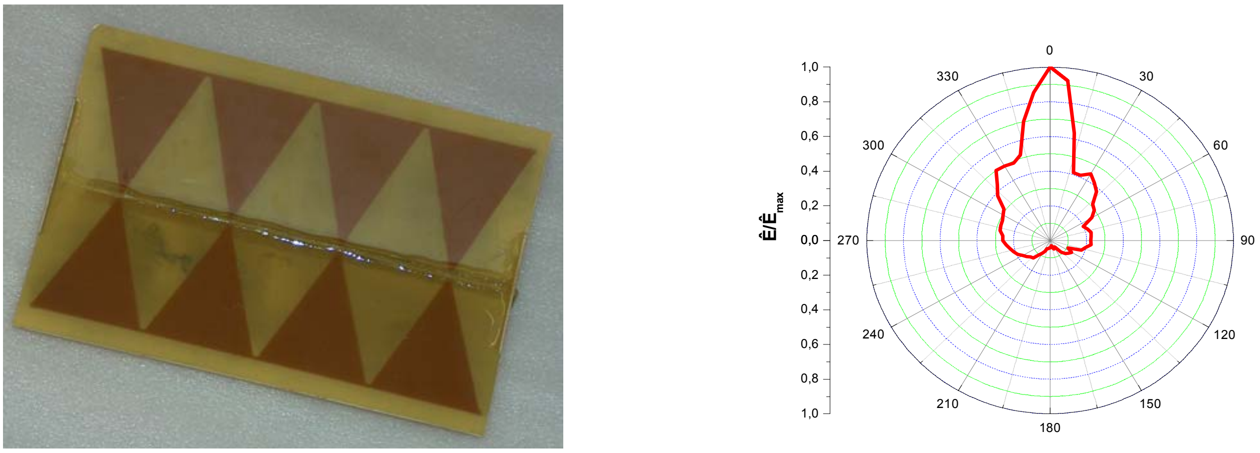

Figure 9 Bow Tie type antenna (300 x 200 mm) and antenna diagram of an array of two Bow Tie type antennas

V. Asymmetric threats

During the last few years Improvised Explosive Devices (IED's) have become a very lethal asymmetric threat for the armed forces in their peace keeping missions. In Figure 10 a characterization of IEDs based on there Trigger mechanism is shown. UWB-system are able to prevent remote controlled IEDs from detonating by interrupting the communication channel between the command control and the IED or to interfere with the electronic sensor causing it to detonate prematurely.

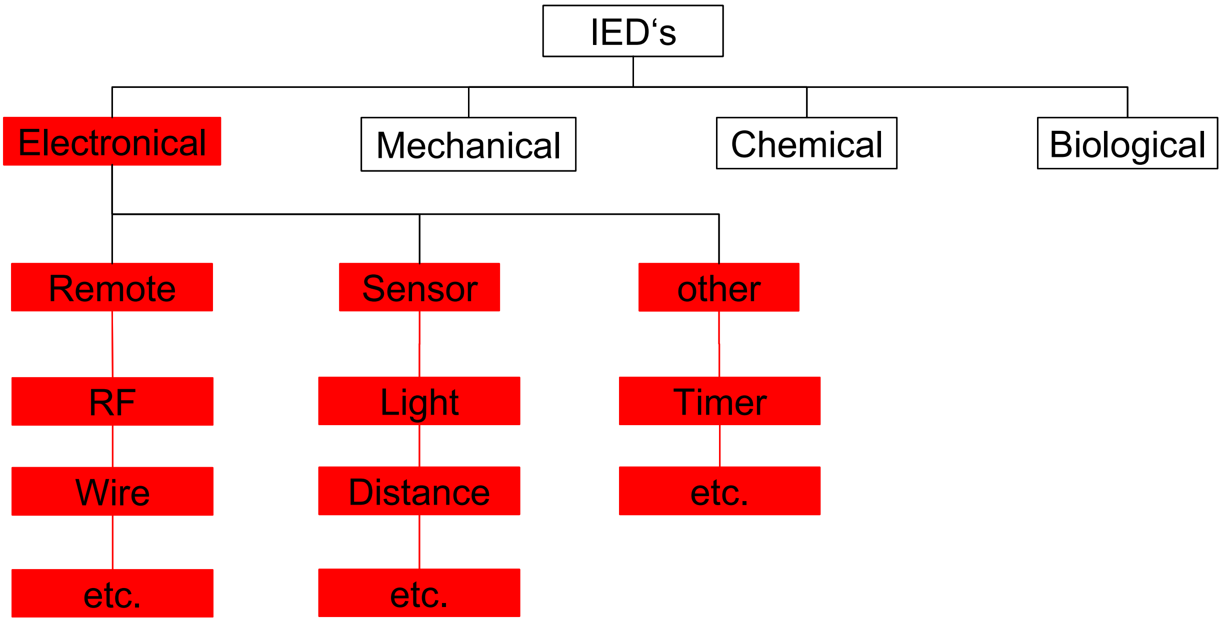

Figure 10 Characterization of IEDs based on there trigger mechanism

IEDs to interrupt the communication

In several tests the UWB system RHL720k has shown that by suppressing or interrupting the communication channel it is possible to prevent RF controlled IED's from detonating. High repetition UWB sources are able to suppress simultaneously all communication channels from some MHz up to 3 GHz (Pager, PRM, Mobile Phones etc.) without knowledge of used frequencies. Figure 11 shows a typical result for commercial walkie talkies.

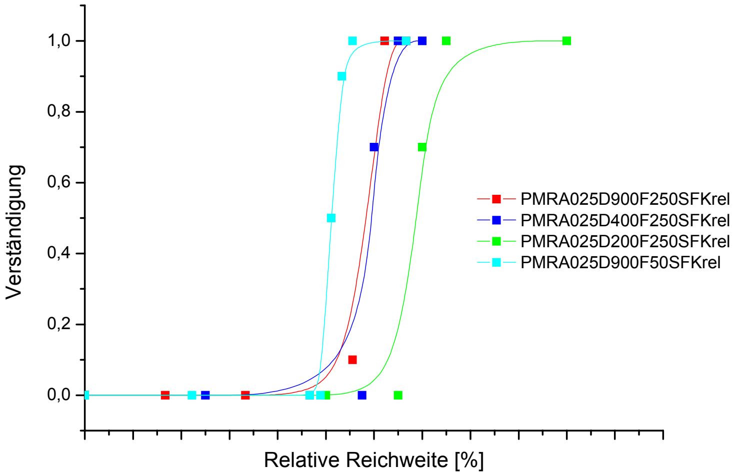

Figure 11 Relative operation distance of RHL350k with Antenna A025

IEDs to detonate prematurely

Beside the remote controlled IEDs there are sensor controlled IEDs. There are various types of sensor, radar, IR, light, ultra sonic etc. By interfering with the electronics or the sensor directly, the IEDs detonate prematurely.

The maximum operation distance depends on the type of sensor or electronics (see). By using different modulation technologies it is possible to reduce the susceptibility threshold of the IED electronics.

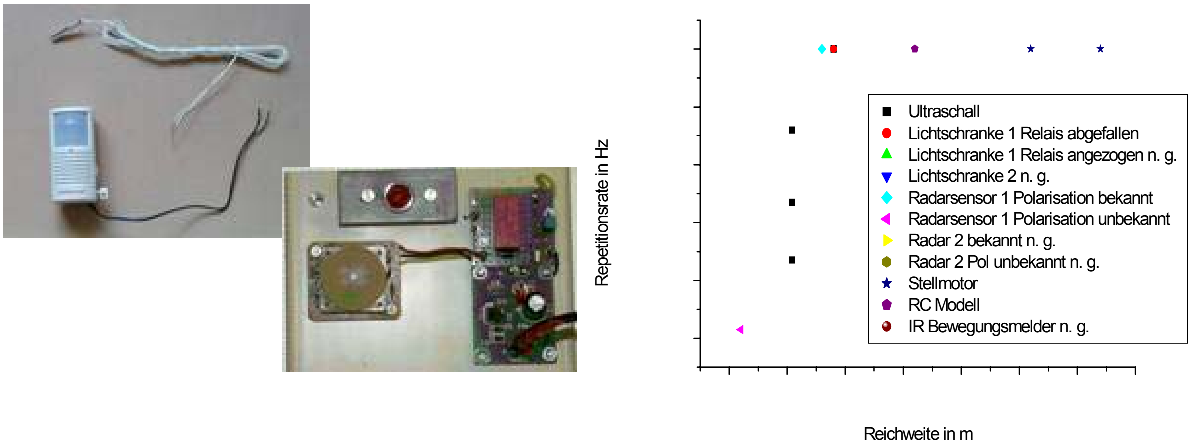

Figure 12 IR-sensors and operation range for different sensor type

The electrical fieldstrength to detonate IEDs prematurely is higher compared to the electrical field strength required to prevent IEDs from detonating.

VI. Conclusion

Semiconductor based sub-ns UWB systems are able to prevent RF-controlled IEDs from detonating or to detonate electronic / sensor IEDs prematurely, depending on the parameters “repetition rate” and “fieldstrength”.

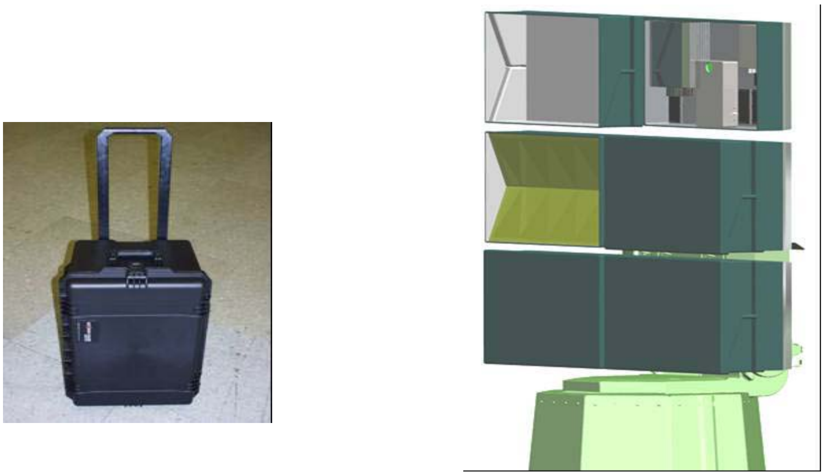

Figure 13 Portable UWB System RHL720K and the RHL120M for extended range application

Based on the test results, two UWB-systems have been designed (see Figure 13). The RHL720K for short range application and the RHL120M for long range application. The prototype of the RHL720K is ready and undergoing field tests. The RHL120M will be ready by the end of this year.

Due to the modular design of these systems it is possible to meet special customer requirements during a short period of time and if desired/necessary a combination with also available DS-sources.