

„Pilotprojekt Digitalfunk Aachen”

Integration of a Federal Border Police Helicopter into a TETRA-System



- Summary -

**Tests and measurements for technical solutions to integrate
TETRA radio terminals into helicopters**

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Federal Border Police

Central Office for Information and Communication

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1. General

On resolution of the Standing Conference of the German ministers of interior of the countries (IMK) the Pilotprojekt Aachen should obtain a concept to built up a nation wide digital radio network for all police forces and public safety organisations. This digital radio communication system has to be an European standard and should be used by all organisations.

On account of the experience with the digital radio system TETRA 25 in the Pilotprojekt Aachen the special operational and tactical requirements of the Border Police Aviation Group should be defined. Technical and tactical solutions have to be worked out to integrate aircrafts in the TETRA system. Specially for the Border Police it is very important to make experience by fitting out a helicopter with a TETRA radio terminal and testing the functionality in a real TETRA system.

2. Special requirements to a digital radio communication system for the Border Police Aviation Group

The Border Police Aviation Group have defined some basic operational and tactical definitions about the functionality of a further digital radio communication system:

Full integration of all aircrafts from the police and public safety organisations (specially for Border Police: helicopters) in a digital radio communication system has to be guaranteed. **The radio link from the aircraft to the fixed system-infrastructure must be established from the ground up to 4000m high (above ground) without any gap and a velocity of the aircraft up to 350 km/h without loss of connection.**

If an aircraft is standing on the ground (e.g. helicopter) the network connection has to be operational in the same functionality as a car mounted radio terminal.

The radio terminals in the aircrafts have to be used in two different operation modes, selected by the users: The trunking mode by using the SwiMI and on the other side the direct mode to establish a direct link from one radio terminal to another without using this infrastructure. If necessary the users in the aircraft must be able to operate simultaneously in two different talk groups on the radio system.



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If the radio terminal in the aircraft is working in trunking mode the digital radio communication system must support the described functionalities (corresponding to the “Schengen Documents”):

- **Group communication** in the whole national network in TMO¹(nation-wide) and in DMO² (with limited functionality)
- **Private calls** between two radio terminals in the whole network
- **Telephone call** (the authority should be defined by the network management)
- **Emergency call**: The emergency call must be sent to all members of the talk group and to the dispatcher. The emergency call must have the highest priority.
- **Short data service**
- **Status message**
- **Data transmitting**: The Border Police Aviation Group is developing a central fleet-management. Beside this management items it is also necessary to transmit actual information (e.g. flight orders, information about landing strips or other electronically documents) directly to the aircraft by using the digital radio system.

The operational and tactical requirements of the Border Police Aviation Group to a further digital radio system are principal described in the TETRA specification (ETSI ETS 300-392-xx). It is important to describe the special requirements towards a radio system, if the radio terminals will be used in aircrafts (e.g. height, speed).

¹ **T**runking **M**ode **O**peration **TMO**, communication by using the switching and management infrastructure

² **D**irect **M**ode **O**peration **DMO**, direct communication between two radio terminals



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3. Necessary preparations for the tests

First Federal Border Police helicopter flight-tests were executed in on January, 16th and 17th 2003 in the region of Aachen (TETRA Radio network of the Pilotprojekt Aachen). Members from the Border Police Aviation Group (responsible for the helicopter, the flight and the safety for the TETRA-equipment) and members of the Central Office for Information and Communication (responsible for the TETRA-measurement and tests) was involved in this trail.

Equipment details regarding the tests are describes below:

helicopter:	<ul style="list-style-type: none">• Eurocopter EC 155B• Type D-HLTK• maximum speed about 324 km/h (175 kts)
TETRA-System	<ul style="list-style-type: none">• TETRA-System of the „Pilotprojekt Digitalfunk Aachen“• Supplier of the system: Motorola “Dimetra 4.x”
radio equipment used in the helicopter:	<ul style="list-style-type: none">• radio terminal: Motorola MTM 700• antenna: vhf/uhf-combined antenna (P/N: 12-328 P 4); Chelton• integration of the TETRA audio signal to the intercom of the helicopter by using the audio interface of the TETRA-terminal



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3.1 EMC measurement and authorization of the TETRA equipment

At August, 29th 2002 there was a EMC tests of the TETRA radio terminal and the measurement equipment, which was mounted into the helicopter. Special certificated members of the Border Police Aviation Group made some tests under free-field conditions to give a authorization for using all this tested equipment temporally in this helicopter.

The EMC measurement was done comparable the EMC test precept 500/18. The results was that all measured values were within their limits and that there was no influencing to other helicopter equipment. By operating TETRA radio terminal, test- and measurement equipment the helicopter flights will not worried.



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4. Examinations and measurements of the TETRA system

4.1 The TETRA air interface under conditions of high velocity

The ETSI specification for the TETRA25 radio system requires a proper radio link between radio terminals and TETRA base stations as minimum up to a velocity of 200 km/h. If TETRA radio terminals are used in aircrafts the speed can be much higher in practice. To verify this problem some special tests were executed to examine the radio link between a TETRA radio terminal (used in the helicopter) and the SwiMI (TETRA base station). The test in detail was as described below: The helicopter flew directly with maximum achievable speed and minimum high towards and across a TETRA base station (in this case: the mobile site of the Pilotprojekt Aachen).

Test-results:

- **During this tests technical problems of the radio link between the TETRA radio terminal and the SwiMI could not be proved.**

This statement is only related to the tested equipment and the TETRA-SwiMI of the Pilotprojekt Aachen.

Test-Conditions:

	flight no. 1	flight no. 2
height of the base-station-antenna:	10 m	10 m
flying speed (about ground) Fluggeschwindigkeit über Grund:	270 km/h	305 km/h
altitude Flughöhe über Grund	40 m	45 m
effective altitude Effektive Flughöhe	30 m	35 m
effective speed (approximately) Effektive Geschwindigkeit (genähert)	≈ 270 km/h	≈ 305 km/h

Extracts from the measurement file



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4.2 Roaming of a TETRA-radio terminal used in an aircraft

If a TETRA radio terminal is used in an aircraft high above the TETRA radio network different conditions has to be observed comparing to a use it on the ground. From a defined flight height a lot of TETRA base stations are principally able to establish a radio link to the radio terminal used in the helicopter. But the necessary partitions between the discrete radio signals from the single base stations (RF field strength of the radio cells) is not present under this conditions at the radio terminal. There are no longer unambiguous criteria for the TETRA radio terminal to establish a radio link to one of this base stations or for roaming.

To verify this topic the helicopter flew with relative high speed and low altitude about the TETRA radio network of the Pilotprojekt Aachen.

Test-results:

- **The using of the TETRA terminal in the helicopter under the described conditions (high speed, low altitude) is normally practicable for the operator without noticeable problems.** The tactical integration of the helicopter by using all services of the TETRA infrastructure is possible.
- Changes of the configuration of the TETRA radio terminal and the SwiMI has direct consequences to the roaming of the radio terminals. Using of preferred base stations (home locations) by the terminal is a good way to reduced not useful changes between the single radio cells.
- During the test flights some radio link errors were noticed. This should be a problem of the roaming of the TETRA terminal between the single radio cells and of interferences.



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Test-conditions:

location	altitude / speed	remark
area of Hückelhoven	275 m above sea level.; 285 km/h (mean value)	First there was a radio link to the BTS “Aachen Headquarter”, then roaming to BTS “Halde”
area of Viersen	350 m above sea level 245 km/h	Interrupt of the radio link between the radio terminal and the BTS “Halde” because of exceeding the maximum radio distance of 58 km. Verifying of this flying back to the BTS to establish a new radio link. Repeating of this test under the same conditions and with the same result.
area of Esweiler- Heimbach- Aachen	160 m to 550 m above sea level 235 km/h	The radio terminal established radio links to this BTS: Halde, Kesselhaus, Natoturm, Funkübertragungsstelle, Dreiborn1, Kronprinzen Rast, Stolberg 4 and PP Aachen

Extracts from the measurement files

4.3 Interference problems relating to the altitude

Most of the present mobile radio communication system (e.g. GSM, TETRA, Tetrapol ...) are built up as cellular radio networks. In this case the radio frequencies are repeated in the cellular radio system by a special scheme (called cluster). Theoretical it is not a problem to built up a proper cellular radio network only for using terrestrial radio terminals. If Radio terminals will be fit in an aircraft and then will be used in cellular radio networks there can appears interference-problems.

In terrestrial radio networks the RF-Signals from the base stations and from the radio terminals will be dumped by the surface of the earth. In this case there is theoretical no problem with interferences. In air-ground-air radio networks there is only a little dump of the RF-Signal between base stations on the ground and radio terminals which will be used in aircrafts. For this air-used radio the cells of the radio network are not unambiguously separated. This is the mean difference between a terrestrial and an air-ground-air radio network.

Test-results:

- **In the TETRA system of the Pilotprojekt Aachen there is no guaranty for a proper radio link (without interference problems) between the base stations and a radio terminal used in an aircraft.**
- A special modification of the configuration from the radio network and the radio terminal improved the problems of interferences and roaming of the radio terminal. By using only special base stations with exclusive frequencies ("home location") the visible problems of the terminal in the aircraft became less.
- On account of many roaming processes of the radio terminal used in the aircraft the conclusion is that there are problems with interferences, which appeared in high altitudes.



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Test-conditions:

location	altitude	remarks
area of Eschweiler- Heimbach	1900 m about sea level	The radio terminal of the helicopter has to use these base stations (home location): <ul style="list-style-type: none">▪ BTS Stolberg4▪ BTS Kronprinzen Rast
area of Monschau- Wahlerscheid	650 m about sea level	The radio terminal roamed to base station Wahlerscheid By flying across the base station Natoturm there is no roaming to this radio cell because the base stations Natoturm and Wahlerscheid are not defined as neighbour cells.
area of Walheim	800 m about sea level	Momentary roaming to BTS Monschau, than roaming to: <ul style="list-style-type: none">▪ Dreiborn1▪ Natoturm▪ Kronprinzen Rast

Extracts from the measurement files



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4.4 Test of Direct Mode Operation between two TETRA radio terminals (DMO)

During this test with two TETRA radio terminals using the direct mode the maximum range of this kind of link was tested.

Test-result:

- The maximum range between two TETRA radio terminals using the direct mode is approximately 58 km like the theoretical value. If the radio terminals will be used in the range above 58 km the speech quality will become bad and than the link is lost.

Test-conditions:

To test the maximum range under this special conditions one fixed TETRA radio terminal was used in Swisttal (Motorola MTM700 with a outdoor antenna). The other radio terminal was used in the helicopter. Under this conditions there was a free line of sight between the radio terminals. Both terminals used the TETRA direct mode.

4.5 Appreciation of the subjective speech quality in a TETRA system

Simultaneously with the TETRA-system-measurements the quality of speech in the TETRA system of the Pilotprojekt Aachen should be tested. The quality of speech was tested in trunking mode operation and in telephone mode by using the TETRA-terminal in the helicopter.

Test results:

- **The quality of speech between the radio terminal mounted in the helicopter and a fixed TETRA terminal was subjectively very good. Furthermore there was no problem to establish a telephone call out of the helicopter in acceptable quality without any problems (see also item 4.3 and 4.4).**
- **Compared with an analogue radio system the speech-quality and -clearness in a TETRA system is much better. The helicopter pilots estimated the system as a good solution for their application.**
- **Flight- and other disturbing noise will be reduced by the TETRA radios.**

Remark: At this tests subjective impressions of several persons was used. Technical analysis was not made.

Test-conditions:

During this tests the quality of speech in the TETRA system of the Pilotprojekt Aachen was evaluated subjectively. The trunking mode operation and the direct mode operation was tested directly compared with a analogue radio system. Furthermore a telephone call to the PABX was tested.



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5. Finally appreciation:

- The digital radio communication system TETRA 25 is principal suitable to realize the basic demands of the Border Police Aviation Group.
- In the TETRA system of the Pilotprojekt Aachen there is only a restricted capacity to use data application.
- The ETSI-document (Draft ETSI TR 102 021-8 v0.0.4; Terrestrial Trunked Radio (TETRA); User requirement Specification TETRA Release 2; Part 8: Air-Ground-Air services) shows further solutions to solve interference- and roaming problems.

Remarks: All test results, statements and appreciations are related to the TETRA system of the Pilotprojekt Aachen and under the described test conditions. In the limited timeframe it was only possible to execute the tests described above. For more information about the measurements and tests we refer to the elaborately report. On request we can offer the long version of this report (German language only).

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