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TECHNICAL REPORT

Terrestrial Trunked Radio (TETRA);
Voice plus Data (V+D);
Designers' guide;
Part 6: Air-Ground-Air

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee TETRA and Critical Communications Evolution (TCCE).

The present document is part 6 of a multi-part deliverable covering Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Designers' guide, as identified below:

ETSI ETR 300-1: "Overview, technical description and radio aspects";

ETSI TR 102 300-2: "Radio channels, network protocols and service performance";

ETSI TR 102 300-3: "Direct Mode Operation (DMO)";

ETSI ETR 300-4: "Network management";

ETSI TR 102 300-5: "Guidance on numbering and addressing";

ETSI TR 102 300-6: "Air-Ground-Air".

Modal verbs terminology

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1 Scope

The present document is written as a "Read-me-first" manual or "Getting started with TETRA Air-Ground-Air". It is not intended to be a guide to the TETRA Air-Ground-Air standard nor an authoritative interpretation of the standard. If any conflict is found between the present document and the corresponding sections in the TETRA standard then the standard takes precedence.

The reader of the present document is assumed to have a working knowledge TETRA technology. The guidance provided in the present document is prepared with the experience of implementing an Air-Ground-Air to an existing national network.

The aims of the present document are:

- to introduce and detail the different aspects of Air-to-Ground communication in a TETRA network;
- to show the reader that Air-Ground-Air is an integral part of a TETRA network when required;
- to provide the reader with sufficient knowledge to engage in qualified discussions with the equipment and service suppliers;
- to expose the reader to the specific language and technical terminology used in the present document;
- to enable the reader to understand the flexibility in system design, system network topography, system availability, various modes of operation and security features;
- to provide basic guidance on optimizing a TETRA network when including an Air-Ground-Air element.

The present document provides guidance on the requirements for an Air-Ground-Air service and how best to implement an AGA service.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

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The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ECC/DEC/(06)05: "ECC Decision of 7 July 2006 on the harmonised frequency bands to be designated for Air-Ground-Air operation (AGA) of the Digital Land Mobile Systems for the Emergency Services".

[i.2] ETSI EN 300 392-2: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

[i.3] ETSI EN 300 392-7: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 7: Security".

[i.4] TETRA MoU - TTR 001-16: "TETRA Interoperability Profile - Part 16 (Air to Ground)".

[i.5] Recommendation ITU-R P.528-2: "Propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

path delay function: cell reselection initiated by path delay

NOTE: The time taken for signal to perform a round-trip between the MS and Cell is known as the "Path Delay". When this time exceeds a preset value the SwMI informs the MS that maximum path delay is exceeded and causes the MS to initiate cell reselection.

Preferred Location Area (PLA): set of cells MS prefers against other cells

NOTE: A number of Location Area Codes may be programmed into the MS. The MS on receiving one or more of these LAs in the neighbour list of the cell it is affiliated to will "prefer" to use the cell associated with one of those LAs. Mobility to and away from such cells is defined in ETSI EN 300 392-2, clause 18 [i.2] and TETRA Interoperability Profile 16 [i.4]. PLAs may also be known as "Home Location Areas".

RF carrier: distinct radio frequency on which radio channel may be active

Subscriber Class (SC): subdivision of the subscriber population

NOTE: There are 16 subscriber classes defined for use on TETRA networks. Those 16 classes are divided into 3 groups, Highly Preferred Subscriber Class, Preferred Subscriber Class and (Basic) Subscriber Class. Mobility between the 3 groups of subscriber class is defined in ETSI EN 300 392-2 [i.2] and TETRA Interoperability Profile 16 [i.4].

V+D operation: mode of operation for communication via the TETRA V+D air interface which is controlled by the TETRA Switching and Management Infrastructure (SwMI)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AGA	Air-Ground-Air
AGA_MS	Air-Ground-Air Mobile Station
AGL	Above Ground Level
ATG	Air To Ground (Also A2G)
BS	Base Station
DC	Direct Current
DMO	Direct Mode Operation
ECC	Electronic Communications Committee
EIRP	Equivalent Isotropic Radiated Power
EMC	ElectroMagnetic Compatibility
HF	High Frequency
HPSC	Highly Preferred Subscriber Class
LA	Location Area
MCCH	Main Control CHannel
MMI	Man Machine Interface
MS	Mobile Station
PD	Packet Data
PLA	Preferred Location Area
PSC	Preferred Subscriber Class
PSS	Public Safety Spectrum
PTT	Press To Talk switch, otherwise known as pressel
RF	Radio Frequency
RSSI	Radio Signal Strength Indication
RX	Receive
SC	Subscriber Class
SwMI	Switching and Management Infrastructure
SWR	Standing Wave Ratio
TMO	Trunked Mode Operation
TX	Transmit
TX/RX	Transmit/Receive
V+D	Voice plus Data (trunked infrastructure)
VHF	Very High Frequency

4 What is different about Air-Ground-Air operation and why is it needed?

4.1 General

TETRA radio networks are, in the main, built to provide communications where most subscribers are operating terminal equipment at sea or at ground level. There are a number of users, however, whose communication needs require operation at thousands of feet above ground level.

Air-Ground-Air (AGA) operation, also known as Air-To-Ground (ATG or A2G) is a TETRA radio service designed to provide communication between radio users operating from airborne assets and ground based operatives including radio users and dispatchers. The airborne assets typically will be comparatively small in number operating comparatively infrequently. However once they are operational their effectiveness is highly valued.

Most TETRA radio networks are primarily designed as a cellular network providing a land-mobile radio service, so significant design changes have to be implemented to service the requirements for effective AGA use.

The AGA service is provided by deploying an overlay network of Radio Cells or "Air Cells" that provide the user with communications typically from 500 feet (150 m) upwards.

4.2 Spectrum

The spectrum for AGA use is reserved solely for AGA purposes. There are several reasons for this, including:

- Radio channels are a scarce resource. Fortunately they can be re-used at a distance. This is possible due to the path loss caused by distance, landscape and buildings. In land-mobile networks the re-use distance is typically 50 km due to the high path loss of landscape and buildings. Path Loss at altitude is much less than at ground level. Transmitting at altitude on a land mobile network would result in interference on several land-mobile Base Stations that re-use the same radio channel. The EU-wide network plan, see annex A, if followed closely will minimize co-channel interference to acceptable levels. An internationally agreed frequency allocation is easier to implement to minimize interference between networks, refer to ECC/DEC/(06)05 [i.1].
- A small number of widely spaced radio cells supplying service for AGA purposes.
- The cells will radiate at lower power than cells used in the ground network.

5 Technical Design

5.1 Concept of Overlay Network

Due to the limited range of RF signals radio networks normally have a cellular structure where channels are re-used at a regular distance. If the terrestrial network with typical cell sizes of 8 km radius were planned in such a way that it allowed aircraft communications at normal operational attitudes for public safety or private mobile radio users, more than 1 000 channels would be required to avoid co-channel interference. As the available spectrum will support many fewer channels, this is clearly a non-viable technical solution. An efficient means of using the available spectrum is outlined in the following paragraphs.

Operators should answer this by deploying two networks - one optimized for terrestrial use and a second network designed for airborne radios.

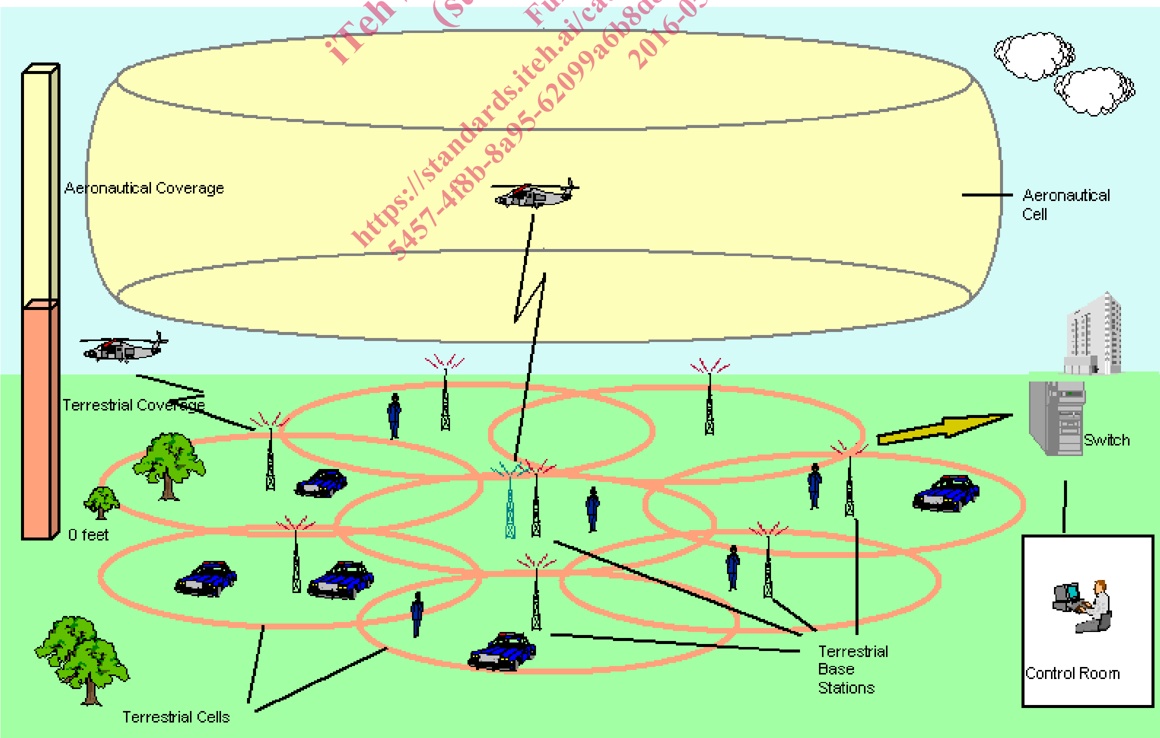

Figure 1: Terrestrial and Air-Ground-Air network

The terrestrial network is planned to the normal guidelines, whilst the AGA network is frequency planned specifically to allow for long frequency re-use distances. In order to maintain spectral efficiency, the AGA cells, here after referred to as "Air Cells" are spaced wide apart and typically have only a single RF carrier at each radio cell.

AGA terminals will roam seamlessly across the two networks without user intervention. The terminals design for use in the AGA service will additionally prefer to use the AGA network, utilizing mobility management techniques described later. Similarly, terrestrial terminals will be restricted to the ground network using the same techniques. As both networks will offer the same services and facilities, the user (either ground or Air-Ground-Air) is not expected to be aware of which network they are using.

The operational design is that the aircraft radio(s) will use the terrestrial network from ground level to an altitude where the AGA signal is received at the value "Radio Usable"; to prevent co-channel interference to ground cells the handover to an air cell should occur before an altitude of 500 feet (150 m) is achieved.

On descent, the operational design is that the aircraft radio(s) will use the AGA to an altitude where the AGA signal is received at the value "Radio Relinquishable" and a ground cell signal is received at a stronger level; this design ensures the aircraft radios are most likely to select the local ground cell. Again, this is to prevent co-channel interference to ground cells the handover from an air cell should occur at a low altitude, considerably less than 500 feet (150 m).

All radio cells are configured to broadcast information that allows suitably configured terminals to identify the network type that they belong to them and to handover to the appropriate radio cell. This assumes that certain other conditions are met; for instance, minimum received signal strength.

5.2 Spectrum Allocation

With ECC/DEC/(06)05 [i.1] a quantity of spectrum has been reserved for public safety AGA operational purposes in the PSS allocation. This reserved sub-band is the upper end of the PSS allocation. It consists of 8 channels reserved exclusively for AGA operations and an additional 2 optional ones to be utilized on the operators needs.

Figure 2 illustrates the European-wide harmonised spectrum layout for public safety networks.

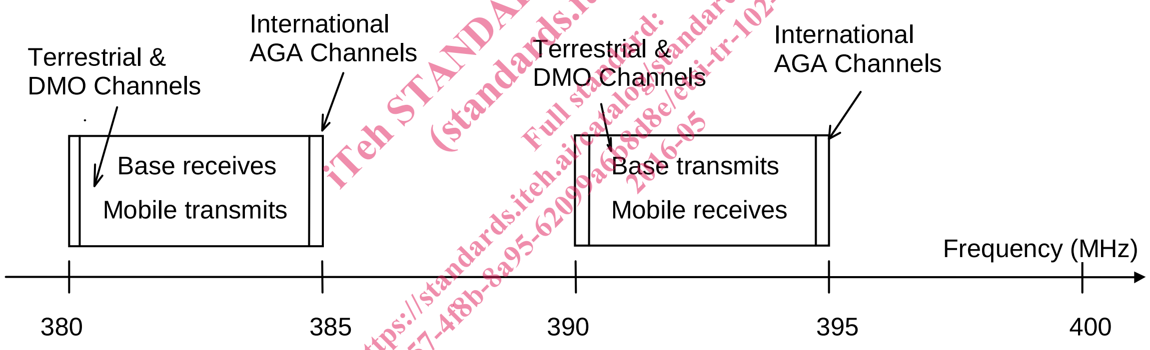

Figure 2: European Harmonised Spectrum Allocation in the 380 MHz to 400 MHz frequency range for Public Safety

5.3 Non-Harmonised Frequencies

Where the service requirements of individual operator or country calls for extra AGA RF carriers are required these additional carriers for AGA use, these carriers will have to be allocated from the terrestrial sub-band then consideration to exported interference to neighbour authorities and operators be undertaken as part of the planning process. It is worthwhile reviewing those frequencies when setting up bilateral agreements between countries.

5.4 Cell Operational Size

Clause 4.2 describes why the operational footprint of an air cell is much larger than a ground cell as in "free space" the path loss is much less. Due to line-of-sight propagation the usable signal from an air cell can extend hundreds of kilometres, depending on altitude; such distances will take the signal a finite time to cover those distances. It is important that the round-trip time of the signal taken to transit between the BS and MS should not exceed the guard time between timeslots.

5.5 Neighbouring

To allow smooth cell reselection in the AGA network and smooth switching between the terrestrial and the AGA network neighbour cell relations have to be defined in the TETRA network.

The neighbouring for AGA purposes needs to be considered in 3 ways.

Unlike the neighbouring for terrestrial cells where the cell to cell neighbouring is normally limited to the immediate, contiguous, neighbouring cells and is reciprocal this is not true of neighbouring to and from air cells. This is due to there being many more ground cells compared to air cells in any network.

Cell neighbouring type 1 - Ground cell to air cell (as known as "Upwards" neighbouring):

- All ground cells that are under the operational area of an air cell should list that air cell in its neighbour list broadcast. If a ground cell is located where more than one air cell may provide service then all these air cells may be included in the neighbour list.

Cell neighbouring type 2 - Air cell to air cell (as known as "Sidewards" neighbouring):

- Neighbouring air cell to air cell should list the immediate or contiguous neighbours only, typically no more than eight dependent upon frequency reuse pattern, ground terrain and the number of air cells.
- In mountainous regions air cells may be located below the level of the surrounding hills and so may not have truly circular coverage.

Cell neighbouring type 3 - Air cell to ground cell (as known as "Downwards" neighbouring):

- Neighbouring from air cell to ground cell should use the following recommended priority order:
    1) The ground cell that serves the operating or home location (air field, helipad) of aircraft that operate within the air cells area.
    2) Any other regularly used airfields or helipads within the air cells area.
    3) A selection of ground cells using different frequencies to the above sites dispersed at intervals within the air cells area. This will allow a better transition to the ground network throughout the air cells operating area. Typically the operating authority will chose no more than 20 ground cells for inclusion in the broadcast neighbour list.

5.6 Subscriber Class

The following information explains how Highly Preferred Subscriber Class operation can be used to aid aircraft communications.

Subscriber class 2 has been adopted and documented in ETSI EN 300 392-2 [i.2] and TETRA Interoperability Profile 16 [i.4] as the recommended subscriber class value for AGA operations therefore AGA radios should be configured to be member of Subscriber Class 2, which is defined in ETSI EN 300 392-2 [i.2] and TETRA Interoperability Profile 16 [i.4] as a Highly Preferred Subscriber Class (HPSC). Ground radios should be configured not to be member of Subscriber Class 2. Subscriber class 1 is also a HPSC value; typically this subscriber class value will be used for other purposes.

Ground cells should normally be configured to broadcast that they do not support HPSC or PSC classes of subscriber class, but only normal Subscriber Classes, typically SC14 or SC16 only. Air Cells should be configured to broadcast support for the Highly Preferred Subscriber Class SC2.

When an aircraft departs, the AGA radio will most probably be registered to a Ground cell. The Ground cells broadcast neighbour list will contain at least one air cell identity including its subscriber class (flag 2, HPSC). The AGA radio monitoring the neighbour cells will, once the received signal of the air cell has reached "Radio Useable" for over 5 s, roam to the air cell even if, or when, the present serving ground cell is received at higher signal strength. For full guidance refer to ETSI EN 300 392-2 [i.2].

Air cell to ground cell reselection, i.e. as the aircraft lands, should take place when the air cell received signal strength falls below "Radio Relinquishable" for more than 5 s. The radio should select one of the cells specified in the received neighbour list and select the strongest received signal. If the neighbour list contains a PSC cell then the radio terminal should select that cell provided the received signal strength is over Radio Useable in preference to lower priority subscriber class cells that may be received at higher signal strengths.

The selection of Subscriber Class methodology will require the operator to cause the air cell to broadcast SC2 only and ground cells to not broadcast SC2. The aircraft MSs will only require the appropriate subscriber class values, SC2 and the terrestrial cell subscriber class value(s) setting in the MS configuration. There is no limit to the number of cells, due to constraints in MS design that may be used for AGA purposes within a network.

Additional air cells added to a network will not require commensurate programming work to the MSs.

5.7 Preferred Location Area

The following information explains how Preferred Location Area operation may be used to aid aircraft communications.

Aircraft MSs, if capable in the MS design, may be programmed with a number of LAs; these LAs are known as PLAs. In this case the PLAs programmed into the MSs will be those LAs of air cells.

The number of PLAs that can be programmed into a MS is limited to, typically, between 20 and 32 LAs.

When an aircraft departs, the AGA radio will most probably be registered to a Ground cell. The Ground cells broadcast neighbour list will contain at least one air cell LA. The AGA radio monitoring the neighbour cells will, once the received signal of the PLA cell has reached "Radio Useable" for over 5 s, roam to the air cell even if, or when, the present serving ground cell is received at higher signal strength. For full guidance refer to ETSI EN 300 392-2 [i.2].

Air cell to ground cell reselection, i.e. as the aircraft lands, should take place when the air cell received signal strength falls below "Radio Relinquishable" for more than 5 s. The radio should select one of the cells specified in the received neighbour list and select the strongest received signal.

The selection of Preferred Location Area methodology does not require the network operator to cause the air cell to broadcast differing (subscriber class) values to ground cells. The limited number of PLAs that may be loaded into a MS will limit either the total number of air cells in an operator's network or limit the operational area of aircraft MSs within a network; should an aircraft venture outside of that area with working radios it should be expected that the aircraft radios will attach to terrestrial cells with the likelihood of causing interference to terrestrial cells over a wide area.

However, should additional air cells be added to an operators network then all MSs used in aircraft will have to be re-programmed to add the additional PLAs to the MS programmed configuration.

5.8 Subscriber Class or Preferred Location Area

The previous 2 clauses describe two different means of identifying the air network from the ground network; a choice of HPSC or PLA, one or the other should be employed only. Both methods offer the same MS roaming performance from terrestrial cell to air cell and air cell to terrestrial cell.

Whilst the choice of air cell selection is left to the discretion of the operator the choice of using subscriber class methodology has benefits with the ease of implementation, network expansion and MS programming. The use of PLA methodology may have a benefit in a small network.

5.9 Radio Handovers

In the terrestrial network, handovers take place when the RSSI on the radio's serving cell drops to a pre-determined level, coupled with a neighbouring cell that has a RSSI that is stronger than the serving cell by a specified margin.

Handovers between the ground network and the AGA "overlay" network will occur, in accordance with the operating description for HPSC or PLA in references ETSI EN 300 392-2 [i.2] and TETRA Interoperability Profile 16 [i.4].