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Foreword

This Technical Report (TR) has been produced by ETSI Project Terrestrial Trunked Radio (TETRA).

The present document is part 8 of a multi-part deliverable covering the User Requirement Specifications (URSs) for TETRA Release 2, as identified below:

Part 1: "General Overview";

Part 2: "High Speed Data";

Part 3: "Codec";

Part 4: "Air Interface Enhancements";

Part 5: "Interworking and Roaming";

Part 6: "Subscriber Identity Module (SIM)";

Part 7: "Security";

Part 8: "Air - Ground - Air Services".

Introduction

The TETRA Release 2 suite of standards was mandated in the new Terms of Reference (ToR) for ETSI Project TETRA approved at ETSI Board meeting number 28 (Board 28) on 6th September 2000 [7]. Its aim was to enhance the services and facilities of TETRA in order to meet the emerging user requirements, utilize new technologies and, by maintaining the competitiveness with other wireless technologies, increase the futureproofness of TETRA as the standard for PMR and PAMR worldwide.

The approved programme for TETRA Release 2 covers five work areas, namely:

- high speed data;
- speech coding;
- air interface enhancements;
- interworking and roaming;
- SIM.

The present document provides the User Requirement Specification for the TETRA Air - Ground - Air (AGA) services which is an expansion of the AGA requirements given in TR 102 021-4, clause 4.2.7 [4].

The URS is required by Working Group 3 of EPT to enable the additional standardization of the TETRA air interface and by the TETRA MoU to finalize the creation of a TETRA Interoperability Profile (TIP) for AGA.

1 Scope

The present document provides the user requirements for a TETRA-based AGA service.

The present document is applicable to the specification of TETRA Release 2 equipment.

The AGA User Requirements Specification contained in the present document are based on a study by EPT WG1 which reviewed previous user requirements documentation and considered ongoing implementation work.

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ETSI TR 102 021-1: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 1: General Overview".

[2] ETSI TR 102 021-2: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 2: High Speed Data".

[3] ETSI TR 102 021-3: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 3: Codec".

[4] ETSI TR 102 021-4: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 4: Air Interface Enhancements".

[5] ETSI TR 102 021-5: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 5: Interworking and Roaming".

[6] ETSI TR 102 021-6: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 6: Subscriber Identity Module (SIM)".

[7] ETSI TR 102 021-7: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 7: Security".

[8] ETSI TR 101 987: "Terrestrial Trunked Radio (TETRA); Proposed Air Interface Enhancements for TETRA Release 2; Analysis and Feasibility Assessment".

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

[10] TETRA MoU TTR 001-1: "TETRA Interoperability Profile (TIP) Version 4; Part 1 (CORE)".

[11] TETRA MoU TTR 001-16: "TETRA Interoperability Profile (TIP); Part 16 (Air to Ground).

3 Definitions and abbreviations

3.1 Definitions

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

aircraft: fixed wing aeroplane or helicopter

air MS: TETRA mobile station certified for use in aircraft

TETRA Release 2: work Programme with new terms of reference within ETSI Project TETRA to enhance the services and facilities of TETRA in order to meet new user requirements, utilize new technology and increase the longevity of TETRA within the traditional market domains of PMR and PAMR

3.2 Abbreviations

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

AGA	Air - Ground - Air
BS	Base Station
DMO	Direct Mode Operation
HLA	Home Location Area
LA	Location Area
MAC	Medium Access Control
MS	Mobile Station
PAMR	Public Access Mobile Radio
PEI	Peripheral Equipment Interface
PDU	Protocol Data Unit
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SwMI	Switching and Management Infrastructure
TCH	Traffic Channel
TIP	TETRA Interoperability Profile
TMO	Trunked Mode Operation
ToR	Terms of Reference
Tx	Transmit
URS	User Requirement Specification

4 User Requirement Specification

4.1 General Requirements

The requirements for an Air to Ground service can be summarized as:

1) Air terminals should have the same TETRA services (Mobility Management, voice and data) as terrestrial terminals.

2) The air terminal may need to be approved by the local Aviation Authority.

3) There is a need for RF co-ordination on networks in the same and in neighbouring countries. The amount of co-ordination may vary depending on the countries involved.

4) The air terminal should operate in either helicopters or fixed wing aircraft.

5) The aircraft may operate in the height range 0 feet to 10 000 feet above sea level (typically 800 feet to 1 200 feet).

6) It is not a common requirement but, there may be specialist requirements for higher altitude operation to be considered as a future user need. An example of this could be fixed wing aeroplanes that are used for patient transport. This may be dealt with on a case-by-case basis.

7) The helicopters operate at a maximum speed of 300 km/h. Fixed wing aircraft may operate at a maximum speed of 500 km/h.

8) The traffic capacity is estimated at around one erlang (total) in typical air to ground networks (data from papers WG19815 and WG19846 - see bibliography). In fact there are likely to be regional variations within any given overlay A2G network and 4 years have passed since these estimates. The traffic forecasts are likely to have changed and regional impacts will have to be introduced but the important point is the volume of traffic will be very low compared with that found in the terrestrial networks. Also note the peak traffic may be higher because there may be more than one air MS per aircraft

9) There is a need for inter-network co-operation. An aircraft flying from any European country (e.g. Greece) should be able to use an air network in any other European country (e.g. Finland) and all those in-between.

10) A necessary step from the interoperability requirement is that the service must be flexible and easy to manage.

11) The number of air terminals in a network is typically in the tens (20 - 50). Depending on the country, this can be equated to around 1 aircraft per several (2 to 5) thousand square km.

4.2 Air to Ground Implementation

The implementation of an air service must use standard TETRA V+D air interface, base stations and terminals with only slight modifications to take account of the special needs. This approach will mean that all the services that are available to terrestrial users are also available to air users. It is also a practical approach as there will be many legacy MSs (on terrestrial networks) when the Air to Ground service is introduced.

The direct use of the normal TETRA terrestrial network has been rejected, as the interference introduced by aircraft would be impossible to counter using techniques such as directional antennae and RF planning.

To overcome the co-channel interference to/from the air MSs, the air to ground implementation will employ an overlay network for the air terminals. This overlay network has its own band of frequencies. This overlay network can be "thin" as the propagation losses in free air are small and the level of traffic needed is also small.

The air terminal should be allowed to use the terrestrial network when it is "on the ground". Without this feature the overlay network would have to duplicate the coverage of the terrestrial network. For this network recognition to be possible the air terminal and the terrestrial terminal must be able to distinguish between the two networks (terrestrial and air overlay). Note; it will not necessarily be possible to use network identifiers such as MNC to distinguish the air overlay network from the terrestrial network.

The differences between the overlay network and the terrestrial network are more in the area of frequencies, BS placement and antenna configurations.

Operators have started to roll out overlay networks for use by airborne air terminals.

4.3 Signalling

4.3.1 General

In general, the air interface signalling will be identical to that of a terrestrial TETRA terminal. The only difference will be the need for some cell reselection modifications and to take account of the low propagation losses in free air.

4.3.2 Cell Reselection

To employ a cellular infrastructure for the air service, the consideration of cell reselection signalling has lead to suggested modifications in air interface operation. The changes are made in the TIPs rather than the air interface itself. The TETRA air interface standard was optimized for terrestrial operation where the propagation environment is different from that found in air to ground use. It is recognized that handover performance for MSs in the air may sometimes be compromised. This depends on the exact implementations that will be used for cell reselection in the air to ground service. It is therefore important for manufacturers to carefully consider handover for the MS.Improvements proposed in TETRA 2 Air Interface Enhancements may improve handover in the air to ground service, especially the changes to the power control element defined in TR 101 987 [8], clause 5.2.2.3. This suggested introducing a new value of "nearly maximum path delay" to warn in advance that maximum path delay is being approached so that cell handover can be achieved in a controlled manner. The current air interface standard EN 300 392-2 [9], clause 21.5.3 has only one value for maximum path delay exceeded, which can only be indicated after link failure.

Some common factors to be considered are:

1) SwMI and MS should include parameters that will help identify the air overlay network and encourage MSs to stay on the appropriate one.

2) Every terrestrial base station must have at least one air cell in its neighbour list to support fast selection of the air overlay network. It is recognized that this requirement may have an impact on the terrestrial scanning performance. The impact will depend on the number of terrestrial neighbours.

3) The neighbour list for air cells needs careful consideration. It is expected that each air cell will overlay several terrestrial cells. Every air cell should have at least some of these terrestrial cells as neighbours. The choice of terrestrial cell neighbours will be network dependent. Non-optimal neighbours may cause a break in service as the aircraft lands.

4) To enable the MS to gather neighbour information by monitoring, the SwMI must broadcast the required knowledge in the neighbour cell information element (LA or subscriber class). These are optional elements and must be checked by the MS.

4.3.3 Moving from terrestrial cell to air cell

4.3.3.1 General

The air MS must register on the air cells as soon as possible after take-off to guard against the air MS producing co-channel interference on the rest of the terrestrial network. The Air to Ground TIP [11] includes this requirement.

To this end there are two proposals to encourage air MSs to look for air cells in preference to terrestrial cells. The differences in the two approaches may mean that one implementation is preferred in any particular network to the other approach. Note that inter network operation will mean that all interested networks should take account of any difference between the two approaches.

If both proposals are used (in different networks) there will need to be a definition of the interaction of the two methods.

Moving from a terrestrial cell to an air cell is similar to the normal terrestrial handover and so no problems are expected with this aspect of air to ground use.

4.3.3.2 Preferred location area

In this approach the MS is programmed with a list of air cell location areas representing "preferred Location Areas" or Home Location Areas (HLA). During operation the MS continually looks at the neighbour cell information broadcast looking for cells that are members of this list.

When a MS sees a cell, which is a member of the HLA list and is radio useable, it will select that cell regardless of the RSSI seen on a cell that is not a member of the list. This is part of the Air Interface standard [9], clause 18.3.4.5.7 but is "optional".

4.3.3.3 Highly preferred subscriber class

In this approach there are two provisioning items. The MS is programmed with a subscriber class representing air cell terminals and the air cells are programmed to broadcast support of the same subscriber class. The standard allows for MS provisioning of subscriber class to be temporarily modified over the air interface at registration.

During operation the MS continually uses the broadcast neighbour cell information to look for cells that support the "air cell" subscriber class.

When an MS sees a cell, which is broadcasting support of the air subscriber class and is radio useable, it will select that cell regardless of the RSSI seen on a cell that does not support the air subscriber class. This is part of the Air Interface standard [9], clause 18.3.4.5.7 but it may be "optional".

4.3.4 Moving from air cell to air cell

This mode of handover is the one most likely to be subject to limitations of a cellular structure used in the terrestrial network. Such a structure relies on the RSSI reducing significantly as the MS moves away from a BS and behind obstructions.

Due to line of sight free-space propagation characteristics, it is unlikely that the normal method of measuring RSSI will result in successful handover. This is because all air cells will have comparable RSSI unless the aircraft is flying at low altitudes. This means that the cell boundary might not be well defined and that an aircraft will not know which neighbour cell is in the direction in which the aircraft is moving.

The user will notice this handover issue most when in traffic and dropped calls may result unless special techniques are used. When the air MS is idle the probability of user impact is low.

Note that a large cell radius reduces the impact of this problem, as it is less likely that the MS will cross a cell boundary.

The most likely method for an air MS to initiate cell reselection will be for the SwMI to indicate a link failure as a result of "Max path delay" exceeded.

The SwMI must support the reporting of maximum path delay exceeded.

The fact that the max path delay has been exceeded can only be recognized by the SwMI if the MS sends signalling to the BS.

In traffic the signalling will be constant when transmitting.

If the first signal, which exceeds the max path delay, is call set up related, that call set up will fail. For this reason the MS should be prompted to send some signalling whilst not in traffic.

Note that the handover possibilities will be improved if the "nearly maximum path delay" element suggested in TR 101 987 [8] is accepted.

There appear to be four possibilities for the sending of messages to measure the path delay:

1) The SwMI to poll the MS with a "presence check".

2) The air MS sends a periodic null PDU with a frequency defined at registration.

3) An air MS programmable parameter, which causes transmission of a PDU (e.g. NULL).

4) An external application could be used to send a status message to the SwMI.

1) above has no air interface changes but has implications in the SwMI design.

2) above has been defined in the existing Air to Ground TIP [11] and introduces air interface signalling which is addressed in an ETSI CR to EN 300 392-2 [9].

3) above needs a new parameter in the MS. It also needs the BS to support the required layer-2 response (power control element of MAC resource) to unexpected signalling.

4) above has no implications on MS or BS but rather the air MS needs an application designed and fitted (internally or via the PEI).

From a user requirement it does not matter which method is used provided there is complete interoperability between SwMIs and MSs using different methods.

4.3.5 Moving from air cell to terrestrial cell

In this case the air MS must hold on to the air cell as long as possible.

To effect satisfactory handover performance the air cell must have some terrestrial cells in its neighbour cell list. These will need optimization otherwise the list will be too long. It is suggested that a list of important terrestrial cells (e.g. airports) be used as neighbours to the air cells.

For the "important" cells (that are in the air cell's neighbour cell list) handover performance is expected to be similar to terrestrial handover. It uses the broadcast cell reselection parameters and RSSI measurements in the same way as terrestrial cells.

For the other terrestrial cells, i.e. ones that are not in the broadcast neighbour cell information of the air cell, cell selection to them is not expected to occur until cell selection on the all of the cells in the neighbour cell information has been attempted. Foreground scanning may need to be performed in order to select other terrestrial cells and the air MS is expected to be out of service whilst this cell selection and subsequent successful location updating is performed.

NOTE: Terrestrial cells that are not neighboured to an air cell might always suffer link failure and therefore not provide service to an air MS as a consequence of the RF planning and topography of a particular TETRA network.

4.3.6 Neighbour cell monitoring

The air MS has a particular interest in rapid neighbour monitoring when it is registered on a terrestrial cell as the MS is searching for an air cell (when it takes off).

The air MS could be defined to scan the air cell more often than the terrestrial cell.

This is not a standards change but the users consider that this should be put into an operator's air MS specification as a guide.

Helicopters can climb at a maximum of 1 000 feet per minute (at sea level). Given that co-channel interference can be severe at heights of more than 100 feet the air MS should be able to select the air overlay network in less than 6 seconds. This means it should be able to monitor the air cell neighbour and decide on handover to the air cell within 6 seconds.

4.4 Wide band noise

The use of a different air to ground frequency sub-band is expected to eliminate co-channel interference with the terrestrial network. In considering wide band interference the effects on the terrestrial network of air MSs and the inverse effect of terrestrial BSs on air MSs should be considered. It was concluded that to avoid the air MS interfering with the terrestrial BS, the maximum power of an air MS should be limited to 25 dBm. For the other direction planners should take care to avoid air cell borders coinciding with terrestrial BS locations. It would be advisable to select frequencies far away from the air band if this was unavoidable.

4.5 Large radius cells

4.5.1 General

The current range of a TETRA cell is limited at 58 km by the size of the gap between adjacent slots (see EN 300 392-2 [9] clauses 6.4.5 and 9.4.4).

The extension of range in an air to ground network has benefits in two areas:

1) The handover performance will improve;

2) There are benefits in RF planning.

The improvement in handover is important, as the normal cellular methods of RSSI measurement are not always applicable in air services.

For RF planning, the reduction in the numbers of frequencies needed is especially important, as co-ordination of frequencies across borders is needed.

Aircraft operation has two features that make the use of large cells possible.

1) The propagation losses in free air are small.

2) The traffic is light.

Whilst propagation in free air may be theoretically possible at a range of 200 km it is considered that the effect of the earth's curvature, aircraft and antenna heights limits the practical range at about 80 km and such an extension in range would be acceptable

This increase in cell radius gives a two-fold increase in the maximum cell area. The new maximum cell area is around 20 000 square km. This means that the number of air BSs could be reduced to a handful in many European countries.

Three basic options for range extension have been looked at in past studies:

1) Two slot TETRA.

2) Timing advance.

3) Increase in the guard band between adjacent slots.

The use of two slot TETRA was considered for TETRA Release 2 but it was thought too much of a restriction on the traffic capacity. For a single carrier BS there would be only one TCH on that BS. Single carrier BSs are likely to be the norm due to the RF co-ordination requirements of air to ground planning.

The introduction of a timing advance mechanism similar to that used in GSM was felt to be too onerous at this stage.

Whatever option is chosen, there may be BS changes in implementing longer range in this way related to the detection of the training sequence. The increase in range means that the training sequence search window has to be extended beyond that implied in the current TETRA specifications.

4.5.2 Reduced ramp up and ramp down timing

It is concluded that the only practical option is to increase the guard time by reducing the ramp up and ramp down timing of the MS.

An increase of 6 bits in the guard time would give a total range up to 83 (58 + 25) km.

It is worth noting that an MS with faster ramp timings would still be within the standard as there is no minimum specified but a slower MS at the maximum range (83 km) from the BS could interfere with an MS close to the BS if cells with radius of more than 58 km were used.

Feedback from some suppliers suggests that such a reduction in ramp times is within current technology. One supplier has stated the ramp times could be reduced by as many as 46 bits and still meet the adjacent channel and wideband noise performance requirements.

4.5.3 Radio frequency planning

The improvement in RF planning to be gained from an increase in cell radius from 58 km to 83 km could give a maximum reduction in cells by a factor of 2 (83/58 squared).

The resultant distance between BSs (144 km) gives rise to the possibility of a frequency reuse pattern of 7. This is especially important for those operators with international borders and co-ordination requirements. It also increases the likelihood of good handover performance.

The ERC Decision (ERC/DEC(01)20) designates 8 channels for AGA use. Note that there are international discussions (13 Nations Group and working group FM38 of CEPT) that are suggesting to increase this to a total of only 10 channels for use in air to ground networks. This could be accommodated with large cells, as long as not many have more than one carrier.

4.5.4 Border cell configuration

To help co-ordination and cross border interference reduction there are some techniques that would help to reduce the power of the MS near the borders. This does not use new signalling but rather a configuration of existing signalling.

The BS broadcast could be used to reduce the maximum power that can be transmitted by the MS when it is camped on a border cell. The minimum is currently 15 dBm (32 mW). It is unlikely the value can be reduced, as there are too many legacy terrestrial MSs in use to change the air interface signalling. For air MSs it may be possible to set an upper limit of 32 mW at provisioning.

The maximum path delay could also be set to a smaller value for border cells so that the link would be lost at a smaller radius as the aircraft flies away from the cell (towards a foreign cell).

As a further means of reducing the interference area the use of closed loop power control of the MS transmitted signal would enable a lower mean transmitted power than if open loop power control was used. The SwMI would need to support the signalling to tell the MS to apply closed loop power control.

4.5.5 Other impacts

There would be other impacts from an increase in the maximum cell radius.They are not new requirements but rather derived from the main requirements.

1) The BS must be able to detect the training sequence from the "later" bursts from the distant MS. That is the training sequence may appear starting at bits 254 - 274 from the start of the slot that left the BS. This is compared with 254 - 268, which is the current derived space. This group has heard from one supplier that this is possible but needs software update.

2) The SwMI must be capable of measuring the longer path delay (83 km). This is linked to the above.

3) The SwMI must be able of setting "max path delay" to the new maximum (83 km). Again the group has heard that one supplier indicates this is possible.

4) There must be a method of measuring path delay (MS initiated PDUs, SwMI polling, regular MM Status) while the MS is idle so that the SwMI can indicate link failure and the MS can be forced to select another cell. It is open to the suppliers but there is a definite requirement for MS transmissions when idle.

4.6 DMO

Direct Mode will not be used as a general AGA solution. An example of when DMO may be used could be communication from a helicopter to emergency services on the ground prior to landing at an incident in an area where there is no terrestrial coverage or for special operations which do not wish to use the TMO network. This means that DMO has no impact on these recommendations for a trunked AGA service.

DMO should not to be used as a general AGA solution as it provides only a restricted range of services and it is spectrally inefficient compared to TMO.

If airborne DMO were to be used extensively then the effects on co-channel and wide band noise would need to be considered.

4.7 Failure modes

The failure of an MS in an aircraft would be the same as the failure of a terrestrial MS.

The situation is different if a BS from the air to ground overlay network fails. In these conditions, it is likely that air MSs registered on the failed cell will choose a terrestrial BS and register to that cell. This is because the air network is likely to be very thin and overlapping coverage is not planned. In this case the MS will act in the same way as if the aircraft has lost air network coverage because it has landed. Co-channel interference may result, as the air MS will be operating on the terrestrial frequencies. This means the network operator should pay special attention to the air BS alarms.

If an air cell loses contact with the rest of the network and starts broadcasting "System wide Services temporarily not supported", to indicate BS fallback then the MS should stay registered on the air cell, as it should be preferred over a terrestrial cell even if that terrestrial cell is in TETRA Normal Mode. However, if an air MS can scan or monitor a neighbouring air cell as Radio Usable or Radio Improvable which is in TETRA Normal Mode then the air MS should prefer that cell to the serving cell, because it should provide more services.

5 Conclusions on options

A cell extension to 83 km will meet the requirements for AGA operation.

The reduction in MS ramp up and ramp down times is seen as a technically possible way to achieve such an increase in cell radius.

It is suggested that the "highly preferred subscriber class" is the better way to indicate an air cell and to encourage the air MS onto the air network. The HLA approach has limits in the area of interoperability and would entail co-ordination across borders on LA numbering schemes and updates plus MS reprogramming of any changes in any international air service.

6 Enhancements to the standards and TIPs for AGA operation

The following list should be implemented to give a satisfactory AGA service:

1) The SwMI must support broadcast and setting of subscriber class bits.
2) The SwMI must support neighbour broadcasts containing the optional subscriber class element.
3) The SwMI must support the instigation and/or reception of signalling from an idle MS to measure the path delay.
4) The SwMI must support the measurement of the MS path delay.
5) The SwMI must support the indication of "max path delay" exceeded.
6) The SwMI must be able to support an increase in the maximum path delay to greater than 83 km (management, burst capture, decoding and measurement).
7) The MS must be certified for airworthiness.
8) The MS must support highly preferred subscriber class.
9) The MS must support a combined ramp up and ramp down time reduction of at least 6 bits with a common method of reducing the ramp up and ramp down times (e.g. the MS must support a ramp up time reduced by at least 4 bits and a ramp down time reduced by at least 2 bits).
10) The MS must support the signalling method(s) for path measurement chosen in 3) above.
11) The MS must support power control signalling. The use of closed loop power control should be considered for the MS and for the SwMI providing the air cells.
12) A lower Tx power in the non-active state may be needed (see EN 300 392-2 [9], clause 6.4.2.1).
13) The MS must support fast neighbour monitoring.
14) The MS should support faster monitoring of "preferred" cells in the neighbour list (e.g. air, G1, air, G2, air, G3, etc.).
15) Both SwMIs and MSs should support "nearly maximum path delay" if it is introduced as part of the TETRA Release 2 Air Interface Enhancements.

Annex A: Bibliography

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EPT/WG19846: "Aeronautical use in the band 380 - 400 MHz for Dutch security organisations".

History

Document history		
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