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Source:	**NATO Spectrum Capability Panel (CaP3)**
Subject:	**PMSE Equipment EMC Evaluation Requirements**

Group membership required to read? (Y/N) N

Summary:

Any sharing study in the band 960-1164 MHz should take into account the existing Primary service as well as military systems such as Link 16 (also known as JTIDS/MIDS) that are used in several CEPT countries, in particular within NATO countries. In this band, ARNS and GNSS should be protected from any reduction in performance. This applies to military systems when defining national conditions to operate.

In this context all incumbent applications including military applications should be protected from PMSE, potential candidate application to operate in this band.

Furthermore, it should be noted that a theoretical model for DME receiver's susceptibility to extraneous signals could never be developed. Therefore sharing studies involving the DME system as a victim have always required hardware testbeds on a large panel of equipment of various classes and generations in order to allow a military usage in this band.

The attached input paper summarizes measurement campaigns conducted to date in various NATO countries, and the parameters used to simulate operational environments. It has to be noted that the values given for PMSE parameters are only indicative for performing the tests and are not to be taken or understood as protection criteria.

Proposal:

invites SE7 to

- Take the test scenarios and parameters into account during PMSE sharing studies

Background:

NATO CaP3 requested the Link16 Multinational Working Group (MNWG), which accumulated the best experience over many years on Link 16 sharing studies with TACAN/DME and other systems, to provide their expert view on this possible sharing scenario. The attached NATO input is based on the MNWG expertise and has been approved by the CaP3 in Military Session.

North Atlantic Treaty Organization (NATO)

Civil/Military Spectrum Capability Panel (CaP3)

18 September 2017

PMSE Equipment Electromagnetic Compatibility Evaluation Requirements Inputs to SE7

Executive Summary:

This paper provides the CaP3 recommendations in order to study the feasibility of the introduction of Programme Making and Special Events (PMSE) equipment operation in the band 960-1164 MHz in the context of CEPT/WGFM and WGSE studies. The information contained in this paper was mainly provided by the Link 16 Spectrum Multinational Working Group (MNWG); it has been reviewed, adopted and endorsed by the CaP3 Military Session. Background information and a recommended approach are provided for performing an electromagnetic compatibility (EMC) study and/or testing of the PMSE equipment for possible coexistence with incumbent aeronautical systems. Specifically, the focus includes discussion regarding performing analysis and bench tests between PMSE equipment and airborne and ground Tactical Air Navigation (TACAN), Distance Measuring Equipment (DME), Secondary Surveillance Radar (SSR) and other systems operating at 1030 and 1090 MHz, and systems for use by governmental systems operating in the band on a non-interference basis (NIB) to the primary systems, (e.g. air to air (A/A), maritime mobile (MM)-TACAN, Identification Friend or Foe (IFF) and Link 16). It should be noted that not all of the governmental system equipment listed above are utilized in every CEPT nation.

It is understood that PMSE has the burden to ensure the protection and to avoid any additional constraint with the previously introduced systems, and that robust bench tests and analyses should be considered in accordance with the provided recommendations to determine the conditions of a possible introduction of PMSE in the frequency band. These tests and analyses should be developed to fit the RF environment and assumptions that would apply within continental Europe and are not necessarily the same as those where tests have already been performed.

A summary of equipment that should be tested, national JTIDS EMC test environments and proposed RF equipment EMC test environments are included in Appendix A.

The Link 16 and TACAN/DME RF environments should be as specified for the individual nation doing the test. There are essentially two different types of managed Link 16 geographic area environments in Europe. One environment is managed on a platform centric (PC) basis and the other is on any point in space (APIS) basis. The German FCA, which is an APIS managed environment (100% time slot duty factor in 50 nm APIS) is the basis for a number of FCAs in Europe Austria, Belgium, Switzerland, Germany, Finland, Hungary, Romania, The Netherlands, UK (60% in 70 NM APIS), and it is recommended as one of two good Link 16 RF environment models (see Table A-10) to use on a European level if analysis and testing is not performed on an individual nation basis. It is recommended that each nation perform their own evaluation with their national level derived RF environment parameters and representative communication, navigation and surveillance (CNS) equipment. A second environment that would be useful would be the French Link 16 test environment (see Table A-2) which is a platform centric environment used by the Czech Republic, Denmark, France, Greece, Iceland, Italy, Luxemburg, Norway, Poland, Portugal and Spain. To reflect a good cross section of the Link 16 environments in Europe, both should be tested. Additionally, some nations in Europe employ the short distance echo suppression (SDES) capability for their DME Beacons. In this case, more equivalent point sources for the German and French Link 16 environment (see Tables A-2 and A-10)

for beacon testing may also need to be considered if it produces a greater effect to the TACAN/DME beacons.

The DME RF environment (i.e. Beacon Load, Beacon and Interrogator EPE) is represented in Tables A-3 through A-9.

The densest environment known for Europe should be considered for that environment (i.e. France, Germany and The Netherlands) depending on the equipment being evaluated). This would represent the core area of Europe where the volume of air traffic is highest (see Figure 1).

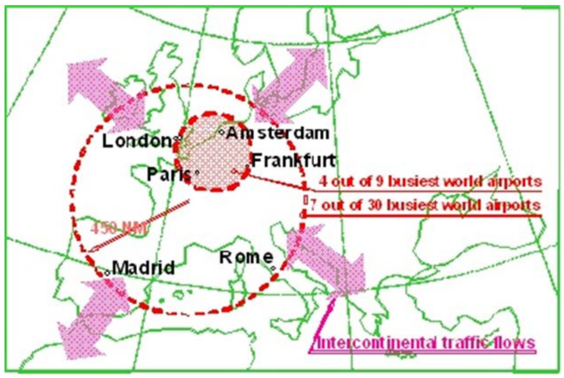

Figure 1 Core Area of Europe Showing Where the Volume of Air Traffic is Highest[1]

Possible test environment scenarios for PMSE equipment analyses are indicated in Tables A-2 and A-10.

In many cases, these test environments representative of continental Europe are independent and different from the predicted test environments assumed for the UK testing[2] and they should be utilized in CEPT tests and analyses. These environments should be considered carefully.

[1] EUROCONTROL Experimental Centre Note No 20/05 entitled, “Air Traffic Freeway System for Europe” November 2005
[2] JCSys Report C053/004/3 entitled, “Test Report for the Coexistence of PMSE with Aeronautical Services in the Band 960-1164 MHz.” 23 September 2015.

Considerations:

The inclusion of new non-safety of life systems in an ARNS and AM(R)S frequency band necessitates robust EMC and regulatory studies, and strict compliance to avoid interference to the incumbent aeronautical and critical military systems. Safety of life aeronautical systems operating in that band must go through a certification process for both the equipment and the operators using the equipment. The band is shared with the military (governmental systems), which are subject to similar civil aviation safety constraints (i.e. Link 16). A system, such as PMSE, would also be expected to have similar requirements placed upon it which would include significant expense of resources to prove compatibility. Additionally, the proliferation of commercial non-safety of life equipment operating in the band can lead to an uncontrolled usage subject to operator error, or illegal or unlicensed operation of PMSE equipment in disregard of various national requirements if equipment was procured in another country with different PMSE limitations. This would not be compatible with the safety requirements of existing and future aeronautical systems.[3] It is important to note that, interference in this band, can have catastrophic and irreversible consequences. ICAO states, "Therefore, the severity of occurrences in this band should invite decision makers and regulatory authorities to more precaution."[4] "Efficient use of spectrum drives our decisions; PMSE sharing the band 960-1164 MHz will produce the opposite result by constraining Civil and Military users of the band and preventing aviation to conduct its modernization program."[5] ICAO has raised their opposition at 88th WGFM Meeting (Dublin, 15-19 May 2017)[6] regarding PMSE sharing without meeting extensive conditions

Of utmost interest to NATO is the fact that the introduction of PMSE equipment into the band 960-1164 MHz could impact the current and future operation of NATO systems that operate in the band, including TACAN, DME, Link 16, IFF/SSR, and UAS/RPAS CNPC system links that may be required for military UAs. Especially at risk is Link 16 which is operated under Article 4.4 of the Radio Regulations (RR) in the band. It should be ensured that the presence of PMSE operations will not affect the level of Link 16 compatibility with the primary aeronautical systems and the necessary Link 16 Frequency Clearance Agreement (FCA) criteria that should be met (i.e. no added Link 16 restrictions either for peacetime or large coordinated operations when necessary)[7]. While interference from PMSE equipment to military ground based equipment could be controlled by applying a necessary separation distance (if those locations are known and can be shared), overcoming the impact to an aircraft receiver which can fly essentially at any point in air space is much more difficult to achieve if not impossible. Thus, for example, PMSE equipment could impact airborne military TACAN operations due to the unknown locations and channel assignments for the associated and paired surface mobile TACAN beacons (e.g. shipboard, and ground transportable beacons). This same impact could result during air to air TACAN operations. In other words, the airborne TACAN channel and aircraft location may not be known making it difficult to deconflict those operations through frequency and distance management.

To authorize a system such as the PMSE, it is envisioned that a conservative robust test bench program between the PMSE equipment (both as a source and a victim) and all types or model numbers of the primary or incumbent aeronautical equipment would be required. The incorporation of a continuously transmitting signal of not specified modulation such as PMSE in this band raises compatibility concerns as receiver requirements for ICAO and governmental incumbent systems have not been specified to handle non-pulsed type modulated emissions. The additional ICAO requirements needed to support a continuously emitting transmitter[8] would require specifications for robust receiver frequency selectivity and immunity from spurious

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[3] Interference statistics have been addressed within the CEPT where over a staggering 1700 cases of interference have been reported to aeronautical services within the CEPT nations; "CEPT ECC Working Group FM Report with subject "Summary of the Annual Interference Statistics Questionnaire for Reported Cases in 2016" dated 19 May 2017

[4] ICAO FSMP-WG/4 WP/24 Working Paper entitled "Agenda Item 9: Interference from non-aeronautical sources Importance of having ICAO position on PMSE sharing the 960-1164 MHz band" dated 30 March 2017.

[5] ICAO FSMP-WG/4 WP/24 Working Paper entitled "Agenda Item 9: Interference from non-aeronautical sources Importance of having ICAO position on PMSE sharing the 960-1164 MHz band" dated 30 March 2017.

[6] CEPT ECC Working Group FM Report with subject, "Final Minutes of the 88th WG FM Meeting" dated 24 May 2017

[7] Such restriction or controls would range from total loss of existing or potential Link 16 authorization to operate to affecting peacetime training by further limiting the levels of operation in a geographic area, disallowing required functionality, restricting location of operations and adding separation distances to other in-band users

[8] ICAO FSMP Letter to ECC WG FM Chairman reference E3 5.15 with subject "Letter from CEPT ECC WG FM, entitled, "request for information on aeronautical, regulatory, legal and technical matters related to the possible sharing the frequency band 960-1164 MHz with wireless microphones"

responses. It is for this reason that all the incumbent system types operating in the band 960-1164 MHz (i.e. manufacturer and Model numbers) must be tested.

This test program must be performed in a simulated maximum RF environment including signals of all systems received under operationally realistic conditions experienced by the aeronautical equipment in the applicable CEPT nations, using the most stringent of compatibility criteria. The PMSE should also be certified to ensure that any equipment waveform characteristics are compatible and designed such that even in cases where the PMSE radio malfunctions, no interference is caused. To meet the latter requirement, monitor circuitry should be considered for integration into the PMSE device which prevents it from operating on unauthorized channels or deviating from transmission characteristics from those that have been determined necessary for compatibility. Also to be considered, is that the operation of PMSE equipment outside the licensed position/country should be inhibited in unauthorized locations as determined by GNSS (also known as "GNSS fencing"[9]). Equipment acceptance testing prior to shipment should be performed to verify that the device is operating in accordance to required compatibility standards. Additionally, the operational use of the equipment must be verified to meet the special frequency management requirements for a system not operating under the proper service allocation in the band (i.e. non-primary user in the frequency band). For example, the military Link 16 radio terminals are required to incorporate EMC Features monitor circuitry and undergo these requirements as a condition for operating as a non-interference system in the band 960-1215 MHz.

To make a case that PMSE can be authorized and operated in the aeronautical frequency band within a nation, it must undergo a rigorous and robust test and evaluation process. This should also consider interference to airborne equipment operation not only in that nation's airspace but also to airborne and ground equipment within a potentially large distance radio line of sight (RLOS) in another country. Criteria for cross border coordination should be established for those cases, when the aggregate signal of PMSE devices operated in one country can interfere with airborne or ground equipment in another country. Cross border coordination for systems and equipment operating on NIB are presently nonexistent in CEPT and need to be established. This would also set the conditions for its operation under frequency management rules. There are important points that must be considered which would include the PMSE transmitter as a source of interference, interference to the PMSE receiver as a victim to the existing RF environment, and with the frequency management process criteria. These points are made below.

General points:

- Safety of life aeronautical systems operating in the band must go through a certification process for both the equipment and the operators using the equipment. The band is shared with the military, which are subject to similar civil aviation safety constraints. A system such as PMSE would be expected to have the same requirement. The ICAO letter has used the JTIDS program as a prime example for the introduction of a non-aeronautical system in such a band.
- It was mentioned during the MNWG meeting that an aircraft Flight Management System (FMS) cannot necessarily determine the Designated Operational Coverage (DOC) for a DME beacon and deselect certain DME's. Therefore, there should be caution taken with respect to analysis assumptions when aircraft are operating in required navigation performance (RNP) airspace with the lateral track navigation being provided by DME/DME during the occasions where GNSS is unavailable.
- It is not the intent to develop an expensive, time consuming and ultimately unsuccessful test program. There may be existing data and receiver measurements that could be used to help more efficiently define CNS equipment to be tested and how to test it. For example, frequency rejection curves presented at the MNWG forum could be used to better select offset frequencies.

The testing of the PMSE equipment transmitter as a source of interference should be performed in accordance with the following points:

[9] Similar to what has been required for non-aircraft Mode S Squitter ADS-B transmissions

- Standardized PMSE waveform characteristics for the band 960-1164 MHz must be developed for which each type would individually be tested and ultimately certified. This would include as applicable but not be limited to the maximum allowable effective isotropic radiated power (EIRP) (peak and average accounting for crest factor), bandwidth, pulse width, spectral emissions criteria (transmission mask), channel assignments and duty cycle. Additionally, future developments of PMSE equipment technology are exploring more spectrum efficient techniques by distributing information on more than once channel using the existing single channel for digital modulation requirements, thus increasing the chance of interference. A standard like ETSI EN 300 422 (Part 1 to 3) with more specifics about the equipment operating in the aeronautical band would be recommended. The use of EMC features circuits/controls should be specified within this standard for PMSE equipment operating in the frequency band and be certified for use by national level authorities.
- All existing and expected manufacturer model numbers (or equivalent) of airborne and ground TACAN/DME, SSR/ACAS/IFF, MLAT, and ADS-B receivers in each of the CEPT nations must be tested to the maximum extent possible using conservative operationally realistic RF scenarios and compatibility criteria. (See MNWG derived table of different national test programs). Proven similar equipment could be exempted with proper analysis within a nation.
- Testing should be performed against the UAT at 978 MHz ±3 MHz with a multiple number of PMSE units. A continuous transmission waveform could cause significant impacts to these ADS-B receivers.
- The assumed TACAN/DME operational environment including parameters such as beacon loading, beacon reply efficiency (BRE), and extraneous pulse environments (EPE) consistent with the CEPT nations should be chosen for performing these tests. Since NATO countries and partners within CEPT countries utilize or host the military Link 16 system, the largest most conservative Link 16 environment contained within the frequency clearance agreement (FCA) conditions in those nations must also be included in the overall RF environment used during the PMSE tests[10]. In other words, the national Link 16 and DME environments within a nation must be fully represented simultaneously when testing the aeronautical receivers (i.e. interfering signals injected into the equipment under test receiver). While recognizing that the conditions for one country are not necessarily applicable for all CEPT countries, using the largest Link 16 environment that is allowed in the FCA of any of the CEPT countries may provide a conservative Link 16 RF environment that should be utilized for testing within the WGSE. The conditions could be performed on a nation by nation basis or in a conservative manner for all the nations in a single test program. The latter would be a better approach for the WGSE. **Appendix A** provides a table that compares the different environments for the TACAN/DME systems that have been used within the different national JTIDS EMC Test Programs to establish the FCA conditions. The appendix also provides the different navigation and air traffic control equipment that has been tested and provides recommendation for the equipment that should be tested. The values in this table have been vetted by the MNWG members. A MNWG recommended environment for use in evaluation Link 16 and PMSE effects to the aeronautical systems is also provided.
- The most conservative Link 16 environment should be considered for the aeronautical equipment testing (for example largest test model environment representing a national Link 16 frequency clearance agreement, or if found to be a more stringent case, distributed environment for TACAN/DME beacon with the short distance echo suppression (SDES) enabled similar to the UK Link 16 test environment and strong foreground environment for TACAN/DME beacons without SDES enabled and TACAN/DME interrogators).
- A proposed PMSE authorization is planning on avoiding 30 MHz around 1030 MHz and 30 MHz around 1090 MHz (+/- 15 MHz). This needs further analysis to ensure it is sufficient to protect all national SSR and IFF if the equipment operates properly. SSR, Mode S based and IFF receiver definitions specify more or less wide receiver selectivity. No receiver selectivity requirements are specified in the EUROCAE MLAT MOPS, since existing requirements were deleted in the present

[10] It is recommended that Link 16 RF environment models for large scale coordinated exercises also be tested (i.e. operations with 200% TSDF to 400% TSDF) as applicable to a national FCA.

version. The actual PMSE equipment transmission spectrum mask must be measured to verify. Standoff frequency requirements for channel planning to maintain compatibility with SSR, IFF, ACAS, and 1090 ES ADS-B, must be established through testing.

- TACAN interrogator, beacon and beacon monitor receivers should be tested as victims in addition to DME interrogator and beacon receivers. This would include effects to the airborne TACAN interrogator operational distance capability, slant range and azimuth determination accuracy, evaluation of the decoded Identification, including audio- and output to the aircraft data bus, and Pulse amplitude modulation (PAM) and reference pulse groups (RPG) detection capabilities and beacon reply efficiency of the TACAN beacons. Testing should be performed at channels across the band both in X and Y modes. It is not realistic to assume that DME and TACAN receiver performance is the same in the presence of potential interference from continuous transmissions such as PMSE equipment. The next bullet provides more detail about interrogator test criteria.

- TACAN/DME interrogator receiver tests must have appropriate conservative compatibility criteria applied such as a Minimal Discernable Signal (MDS) of -99 dBm[11] in the presence of a continuously transmitting signal (this has also been measured to be at weaker signal levels such as -102 dBm), Time to Acquire (TTA), Acquisition Stable Operating Point (ASOP), Breaklock Stable Operating Point (BSOP), P_u (Probability of Update), and identification tone recognition accuracy for both DME- and TACAN-transponder with 30% PAM across all pulses as signal source. Testing should be performed at all off tuned frequencies (to detect spurious response problems) and the image frequency. Testing should be performed that ensures no range errors. **In no case, should safety of life range error readings be displayed to the pilot as a result of interference caused by PMSE equipment transmissions regardless of whether the aircraft receiver is within the beacon DOC area. Such a case was found in the UK testing when multiple PMSE devices were used as a source of interference.**

- A representative number of PMSE devices used at large events must be tested to ensure that there are no aggregate intermodulation effects that would impact the aeronautical receivers. Various frequency channels should also be chosen to ensure that no intermodulation effects fall within the DME receiver front end either in band, at the image frequency or across other parts of the 962-1213 MHz band. Additionally, a representative number of PMSE device types should be part of these tests.

- Testing with adjacent band GNSS receivers should also be performed to determine the highest frequency for single source of PMSE transmissions, and the highest frequency accounting for intermodulation products for multiple sources of PMSE that could be authorized to ensure no impact to the GNSS L5 and Galileo E5 receivers. Using criteria in Resolution 417 (Rev. WRC-15), it is possible that the PMSE equipment should not operate above 1139 MHz. GNSS receiver and repeaters have a slow selectivity roll off for frequencies below 1164 MHz and they are intended to attenuate pulsed signals. Intermodulation effects to GNSS receivers from multiple PMSE equipment transmissions at different channels should also be investigated and ruled out. An evaluation with GNSS repeaters should also be considered.

<u>The analysis of the PMSE receiver as a victim should be performed in accordance with the following:</u>

- From a NATO and national military point of view, since Link 16 operates on a non-interference basis, it is expected that the Link 16 RF environment within a nation not cause effects to the PMSE equipment operation. Even though it has been operating in the band before the PMSE in most nations now authorizing Link 16 and should have priority, there is a lot of risk that Link 16 will not be treated that way in the band, especially when evaluating its use in new nations. There could also be the situation that the PMSE is authorized in a nation prior to Link 16.

- The national environments of Link 16 and TACAN, DME, SSR and IFF must be fully represented simultaneously at maximum power and minimum frequency separation[12] when evaluating the impact on the PMSE receiver. Link 16 operations should be modelled in accordance with the national

[11] RTCA DO-189 document, entitled, “Minimum Operational Performance Standards (MOPS) for Airborne Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 MHz” of 20 September 1985. p. 23.
[12] Minimum frequency separation that would be allowed per frequency management rules.

frequency clearance agreement. All Link 16 equipped platform types and locations must be represented within that model (i.e. not specifically being excluded). A representative PMSE aggregate environment (i.e. planned number of PMSE equipment operating adjacent to the PMSE under test) should be included when measuring interference to the PMSE under test. Appendix A provides a table that compares the different environments that have been used within the different national JTIDS EMC Test Programs to establish the FCA conditions. The values in this table have been vetted by the MNWG members. An example of MNWG suggested environment for use in evaluation Link 16 effects to the PMSE is also provided.

- Simulation of LDACS environments should also be considered as a source of interference.
- The most sensitive PMSE receiver to consider could result in a -115 dBm protection level
- Analysis should be performed on all PMSE receiver types (e.g. IEMs).
- The PMSE receiver frequency selectivity must be determined to ensure protection from SSR transmission frequency emissions that do not fall off in frequency in a rapid manner. High power high antenna gain SSR interrogators could cause effects to the PMSE receiver even with a 15 MHz guard band.
- The definition of PMSE equipment receiver interference criteria is required. For example, lack of discernible audio noises from the interference, “peak deviation” for analog devices or bit/message error rate for digital devices. Additionally, future developments of PMSE equipment technology are exploring more spectrum efficient techniques such as semi-cognitive sensing of the RF spectrum environment and digital modulation techniques need to be considered. There is some information on PMSE equipment usage within ITU reports[13]
- A representative number of PMSE devices used at large events that could be in a single location must be operating in the same RF environment to ensure there are no effects from those devices to the PMSE equipment under test. (i.e. no inter-modulation or cross modulation effects).
- It should be noted that the values for the PMSE that are in the Tables at Appendix A are only indicative for performing the tests and are not to be taken or understood as protection criteria.
- PMSE protection criteria used for the tests should be discussed and defined within the appropriate CEPT working group.

[13] ITU-R Reports BT.2069, BT.2338 and BT.2344

Appendix A.
Comparison of National Link 16 (JTIDS/MIDS) Frequency Clearance Agreement Geographic Area Limits and EMC Test Program Equipment Environments[14].

The values for PMSE that are in the Tables below are only indicative for performing the tests and are not to be taken or understood as protection criteria.

Table A-1. TACAN/DME EMC Test Parameter Comparison Table

Parameter\Nation	US	UK	France[15]	Germany (Draft)	Italy (Draft)	MNWG
FCA Geographic Area Conditions (%TSDF/GA Radius)*	Platform Centric (PC) 100/50 TSDF:100NM, 400/50 TSDF: 200NM	Any Point in Space (APIS) 60/50: 70 NM	PC 100/50: in Varying Geographic Area Radii per platform and power level. Geographic Area Radius by default (worst case) Other Platforms 8 NM for 1W limit 36 NM for 25W limit 100 NM for 200W limit 224 NM for 1 kW	APIS (No RNSS) 100/50: Within 50 NM P>25W Within 18 NM P>1W Within 4 NM All Pwr Potential Future APIS (to protect RNSS) 100/50: Within 70 NM P>25W Within 31 NM P>1W Within 8 NM All Pwr	PC 100/50:100 NM	See CFCC Document
Test environments to support peacetime and large coordinated exercises	[16]**Peacetime** **For DME Beacons:** FG: 50% -33 dBm R1: 30% -60 dBm R2: 20% -75 dBm **R5: 200% -78 dBm** Large Coordinated Exercise 400/50 FG 50% (-33 dBm) R1: 200% (-60 dBm) R2: 150% (-75 dBm)	[18]**DME Beacon with SDES Enabled:** FG: Ring6: 2%: 1.5 NM Ring5: 5.2% at 13 NM Ring4: 8.4% at 24.4 NM Ring3: 11.7% at 35.8 NM Ring2: 14.7% at 47.2 NM Ring1:18% at 58.6 NM BG: Ring6: 59% at 85.75 NM Ring5: 72.67% at 117.35 NM Ring4: 77.95% at 149.05 NM Ring3: 72.99% at 180.75 NM Ring2: 55.59% at 212.45 NM	[19]Estimated (Similar to US): **DME Beacons** 200W FG: 50% between -18 dBm and -45 dBm R1: 50% -60 dBm R2: 200% at the geographic area level (worst case): DME Beacon : -63 dBm	**Beacons** [20]FG1:10%-33dBm to - 21 dBm FG2:40% -33 dBm FG3: 50% -50 dBm BG: 366% -78 to -71 dBm **Interrogators:** FG1 50% -36 dBm FG2 50% -58 dBm BG 366% -78 to -71 dBm **Example for possible PMSE equipment**	**Beacons** [21]FG=50% -33 dBm R1=30% -60 dBm R2: 20% - 75 dBm GEO: 200% -75 dBm	**Peacetime Beacons:** 1. Germany 2. France test environments. 3. UK distributed environment with SDES enabled. 4. UK strong foreground without SDES. **Peacetime Interrogators:** 1. Germany 2. France

[14] Frequency Clearance Agreement FCA information taken from the Link 16 Spectrum Multinational Working Group (MNWG) Notebook dated January 2016.

1. [15] "French MIDS – DME Beacon EMC Test Report", October 1997, Joint Spectrum Center/IITRI (Releasable to NATO, but it doesn't say MNWG)
2. "French MIDS – DME Beacon EMC Test Report Addendum – Strong Foreground Signal Level Tests", October 1997, Joint Spectrum Center/IITRI

"French MIDS – DME Interrogator EMC Test Report", January 1997, Joint Spectrum Center/IITRI (Releasable to NATO, but it doesn't say MNWG

[16] US National Telecommunications and Information Administration (NTIA) Document entitled, "JTIDS Spectrum Supportability Documentation TACAN/DME Beacons" dated September 1996.

Parameter\Nation	US	UK	France[15]	Germany (Draft)	Italy (Draft)	MNWG
	[17]**For TACAN/DME Interrogators** FG: 50% = -42 dBm R1: 30% -60 dBm R2: 20% -72 dBm R5: 200% -78 dBm Large Coordinated Exercise 400/50 FG: 50% (-42 dBm) R1: 200% (-60 dBm) R2: 150% (-72 dBm)	Ring1: 23.59% at 244.15 NM DME Interrogators: FG: 50% -42 dBm R1: 10% within 5 NM (Same for DME Beacons -33 without SDES turned on?) **PMSE:** **FG: 50% -55 dBm** **R1: 10% -60 dBm**	**DME Interrogator:** FG: 50% = -45 to -36 dBm R1: 50% -60 dBm R5: 200% -72 dBm **Example for possible PMSE equipment parameters (to be defined by WGSE/SE7)** FG : 50% -19.5 to -46.5 dBm R1 : 50%, -61.5 dBm R2 : 200%, -64.5 dBm	**parameters (to be defined by WGSE/SE7)** FG1 : 10% -37.5 to -25.5 dBm FG2 : 40%, -37.5 dBm FG3 : 50%, -54,5 dBm BG: 366%, -75.5 to -82,5 dBm		**For PMSE:** Link 16 Environment: 1. Germany beacon environment (modified for PMSE case – see environment in Figures 1 and 2) 2. France beacon environment (modified for PMSE case)
TACAN/DME Beacons Tested	Cardion, SGV, E-Systems DME-P	Fernau 1117 Fernau 2020 Thales 415	Thomson DME 721 (Terminal) Thomson DME 740 Thales FSD40 (en route)		Thales AN453[22]	A good cross section of the beacons used in the UK and French test programs Fernau 1117 Fernau 2020 Thales 415 Thompson DME 721 and DME 740 Thales FSD40
Assumed beacon load And Beacon/Interrogator Extraneous Pulse Environment (EPE)	**DME Beacon: Full 100 Aircraft Load of 2174 ppps.** **Beacon EPE:** **(See Table A-6 below)** **Interrogator:** **LA Basin EPE** **+1 MHz, 1373 ppps, -75**	Y mode: 1200 ppps on-code load (36us spacing) + 300ppps off-code load (12us spacing) X mode: 2200ppps on-code load (12us spacing) + 300ppps off-code load (36us spacing	**DME Beacon Load** : DME 721 and 740 (1997): 1076 ppps DME FSD40 (2025): 1818 ppps **EPE (see Tables A-2 through A-5 below)**			Use most dense conservative beacon loads modes that work for the DME Beacon. Most dense conservative EPE for beacon and interrogators

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[18] Link 16 Spectrum Multinational Working Group (MNWG) Common Frequency Clearance Criteria Document Annex C under UK Geographic Area Test Methodology Description, Figure 1-4 entitled, “TSDF Distribution” dated October 2012
[19] Similar to the US environment. (See document references below the table).
[20] Taken from: German Armed Forces Technical Test Center for Information Technology and Electronics WTD 81 Document entitled, “German Frequency Clearance for MIDS/JTIDS Peacetime Operations and Its Geographical Area” dated 14 June 2005.
[21] Joint Spectrum Center Consulting Report JSC-CR-05-008 entitled, “Multifunctional Information Distribution System (MIDS) – TACAN/DME Beacon EMC Test Report” prepared for the Italian Ministry of Defense dated February 2005.
[17] Joint Spectrum Center document JSC-PR-04-036 entitled, “Summary of MIDS/JTIDS Spectrum Supportability, Interim Documentation, TACAN/DME Interrogators” dated September 2007
[22] The Thales AN453 was determined during the Italian test program to be representative of the FSD – 2, FSD – 5, FSD – 10, FSD – 15, FSD – 30, FSD – 40, FSD – 45, FTA – 10, and the FTA – 43 beacons.

Parameter\Nation	US	UK	France[15]	Germany (Draft)	Italy (Draft)	MNWG
	dBm **+1 MHz 700 ppps, -78 dBm** **+3 MHz 1373 ppps, -90 dBm** **+3 MHz 1373 ppps, -97 dBm**					
Echo Suppression Circuits	N/A	On	FSD 40 (SDES Off)		On	Based on national requirement; For Europe test On and Off
X and Y Mode Channels	Yes	Yes	Yes		Yes	Yes
Interference Criteria	<5% change due to the presence of the JTIDS environment while maintaining a > 70% BRE	70% BRE using a typical antenna gain and cable loss to determine a signal level of -88dBm for Enroute and -78 dBm for Aerodrome DME's	> 70% BRE with DSL ≥ sensitivity + 3 dB		-86 dBm 70% BRE	French test criteria
TACAN/DME Interrogators	DME/N DME 890 DME 1077B KN 63 DME-451 DME-40 KN 65A DME-42 KDM 7000 DME-860E-3 DMS-44A - multichannel DMA-37A - scanner DME-700 - scanner KTU 709(R) KTU 709(B) DME/P ELTA-ELK-7200 MARCONI ANV-211 SEL-400	KN-64 KDM-705A Collins 860 E-3	DME Interrogators Collins 860E-5 Bendix KN 62A TRT TDM-709		FDT-90 SBU-706 KTU-709	Table Collins 860 E-3 French Interrogators -US TACAN Interrogator? -KN63 - GA unit - Commercial unit -scanning DME
X and Y Mode Channels	Yes	Yes	Yes		Yes	Both X and Y
Criteria	-3 dB Delta PTTA 5 Seconds	Achieve ASOP at -78 dBm w/i manufacturer time (typically 5s)	-3 dB Delta PTTA Geographic area test 1 dB PTTA (Geo Off => Geo On)[23]		ASOP at -79 dBm 5 Seconds	French test Criteria

[23] Further description of DME interrogator criteria: "If the change in PTTA signal level was 1 dB or less between the MIDS ON/GEO OFF case and the MIDS ON/GEO ON case, the unit was considered not to be affected by the Geographic Area signal level. This 1 dB criterion is referred to as the Geographic Area cull criterion. This criterion was used to reduce the need for collecting additional test data."

Parameter\Nation	US	UK	France[15]	Germany (Draft)	Italy (Draft)	MNWG
			5 seconds			

Table A-2 French JTIDS EMC Test Environment[24] [25]

Link 16 Point Source:	Time Slot Duty Factor	Signal Level
For TACAN and DME Beacons		
FG1:	50%	-45 dBm to -18 dBm
R1:	50%	-60 dBm
R2	200%	-63 dBm
For TACAN and DME Interrogators		
FG:	50%	-45 dBm to -36 dBm
R1:	50%	-60 dBm
R2:	200%	-72 dBm
Example for possible PMSE equipment parameters (to be defined by WGSE/SE7)		
FG:	50%	-49.5 dBm to -22.5 dBm
R1:	50%	-64.5 dBm
R2:	200%	-67.5 dBm

Table A-3 DME Beacon Load and Beacon/Interrogator EPE

Environment Element	UK	France	MNWG Proposed Environment
Beacon Load	Y mode: 1200 ppps on-code load (36us spacing) + 300ppps off-code load (12us spacing) X mode: 2200ppps on-code load (12us spacing) + 300ppps off-code load (36us spacing	DME 721 and 740 (1997): 1076 ppps DME FSD40 (2025): 1818 ppps	UK load or a maximum load no more than the equivalent of 2700 ppps that the beacon could handle at its sensitivity without the presence of interference.

[24] "French MIDS – DME Beacon EMC Test Report", October 1997, Joint Spectrum Center/IITRI (Releasable to NATO)
[25] French MIDS – DME Beacon EMC Test Report Addendum – Strong Foreground Signal Level Tests", October 1997, Joint Spectrum Center/IITRI
" French MIDS – DME Interrogator EMC Test Report", January 1997, Joint Spectrum Center/IITRI (Releasable to NATO)

Beacon EPE		Table 5	France Table 5
Interrogator EPE		Table 7	France Table 7

Table A-4 French DME Beacon EPE 1997 (DME 721 and 740)[26]

Relative Frequency[a] (MHz)	Pulse Type	Pulse Spacing (µs)	Pulse Rate (ppps)	Signal Level (dBm)
+ 0	DME/N	12	54	-92
+ 0	DME/N	36	54	-91
+ 1	DME/N	12	108	-90 to -96
+ 1	DME/N	21	54	-92
+ 1	DME/N	36	108	-71 to -76
+ 2	DME/N	12	108	-84 to -85
+ 2	DME/N	36	216	-81 to -93
+ 3	DME/N	12	162	-88 to -93
+ 3	DME/N	36	162	-75 to -91
+ 4	DME/N	12	81	-77 to -88
+ 4	DME/N	36	243	-73 to -92

[a] With respect to the beacon receiver frequency (1146 MHz).

[26] French MIDS – DME Beacon EMC Test Report", October 1997, Joint Spectrum Center/IITRI (Releasable to NATO)

Table A-5 French DME Beacon EPE 2025 (FSD40) – based on aeronautical traffic evolution in 2025[27]

Relative Frequency (MHz)	Pulse Type	Pulse Spacing (µs)	Number of aircrafts	Pulse Rate (ppps)	Signal Level (dBm)
0	DME/N	Different	3	144	-79
			3	144	-82
			3	144	-96
1	DME/N	Identical	6	288	-71
			3	144	-79
			3	144	-81
			3	144	-83
			3	144	-96
2	DME/N	Identical	3	144	-78
			15	720	-79
			6	288	-80
			3	144	-81
			3	144	-82
			9	432	-96
3	DME/N	Identical	3	144	-70
			3	144	-71
			3	144	-74
			3	144	-75
			3	144	-79
			3	144	-80
			3	144	-96
4	DME/N	Identical	4	192	-79
			3	144	-80
			2	96	-81
			2	96	-86
			2	96	-96
			1	48	-99

[27] French MIDS – DME Beacon EMC Test Report", October 1997, Joint Spectrum Center/IITRI (Releasable to NATO)

Table A-6 French DME Interrogators EPE 1997 (860-E5, KN62A, TDM-709)[28]

Relative Frequency[a] (MHz)	Pulse Type	Pulse Spacing (On/Off Code)	Pulse Rate (ppps)	Signal Level (dBm)
- 3	DME/N	ON	1000	-83
- 3	DME/N	ON	1000	-66
- 1	DME/N	ON	1000	-82
+ 1	DME/N	ON	1000	-80
+ 1	DME/N	ON	1000	-82
+ 3	DME/N	ON	1000	-83
[a] With respect to the interrogator receiver frequency.				

Table A-7 French DME Interrogators EPE 2025 (KN62A, TDM-709) – based on aeronautical traffic evolution in 2025 [29]

<table>
<tr><th>Relative Frequency (MHz)</th><th>Pulse rate (ppps)</th><th>Signal Level (dBm)</th></tr>
<tr><td rowspan="8">-3</td><td>1000</td><td>-71</td></tr>
<tr><td>1000</td><td>-74</td></tr>
<tr><td>1000</td><td>-78</td></tr>
<tr><td>1000</td><td>-79</td></tr>
<tr><td>2000</td><td>-80</td></tr>
<tr><td>2000</td><td>-81</td></tr>
<tr><td>3000</td><td>-82</td></tr>
<tr><td>3000</td><td>-83</td></tr>
<tr><td rowspan="4">-1</td><td>1000</td><td>-82</td></tr>
<tr><td>1000</td><td>-89</td></tr>
<tr><td>1000</td><td>-76</td></tr>
<tr><td>3000</td><td>-85</td></tr>
</table>

[28] French MIDS – DME Interrogator EMC Test Report", January 1997, Joint Spectrum Center/IITRI (Releasable to NATO)
29 French MIDS – DME Interrogator EMC Test Report", January 1997, Joint Spectrum Center/IITRI (Releasable to NATO)

0	1000	-82
1	1000	-74
	2000	-78
	1000	-82
	1000	-85
2	1000	-75
	1000	-78
	1000	-80
	1000	-81

Table A-8 French TACAN/DME Test Criteria [30] [31]

Table A-8 includes the French DME beacon and DME interrogator test criteria which is the most conservative for European. For the proposed CEPT testing and analysis, this criteria should be used.

Receivers Under Test	Criteria
TACAN/DME Interrogators	-3 dB Delta PTTA Geographic area test: 1 dB PTTA (Geo Off => Geo On)[32] (Need to ensure that range, azimuth, id tone recognition are all part of the evaluation.) 5 second time frame for acquisition; In no cases should a range error be noticed.
TACAN/DME Beacons	> 70% BRE with DSL ≥ sensitivity + 3 dB (Tests should be performed with SDES enabled and disabled).

[30] French MIDS – DME Beacon EMC Test Report", October 1997, Joint Spectrum Center/IITRI (Releasable to NATO)

[31] French MIDS – DME Beacon EMC Test Report Addendum – Strong Foreground Signal Level Tests", October 1997, Joint Spectrum Center/IITRI & "French MIDS – DME Interrogator EMC Test Report", January 1997, Joint Spectrum Center/IITRI (Releasable to NATO)

[32] Further description of DME interrogator criteria: "If the change in PTTA signal level was 1 dB or less between the MIDS ON/GEO OFF case and the MIDS ON/GEO ON case, the unit was considered not to be affected by the Geographic Area signal level. This 1 dB criterion is referred to as the Geographic Area cull criterion. This criterion was used to reduce the need for collecting additional test data."

Table A-9. US TACAN/DME-N Beacon EPE[33]

Relative Frequency to the Beacon Receive Frequency	Pulse Type	On/Off Code	Pulse Rate (ppps)	Signal Level (dBm)
+1	DME/P	On	288	-101 to -104
+1	DME/P	Off	2320	-61 to -92
+2	DME/P	On	1800	-73 to -101
+3	DME/P	On	2512	-49 to -104
+3	DME/P	Off	1616	-52 to -92

Link 16 Environment to be used for PMSE Receiver Tests:

Table A-10: German Link 16 Loads for a TACAN/DME Beacon receivers and Exemple for possible PMSE Equipment Receivers test scenario[34]

Initial scenario for the DME beacons was based on a DME Beacon antenna gain of 9.5 dB. An alternate scenario should be established for a conservative PMSE antenna gain of 5 dB.

For the interference scenario for PMSE receiver all Link 16 foreground loads have to be considered as transmitting at the same time.

JU Nomenclature	Time Slot Duty Factor	Signal Applied to DME	Recommended Signal For PMSE Equipment
FG-1	10%	-33 dBm to -21 dBm	-37.5 dBm to -25.5 dBm
FG-2	40%	-33 dBm	-37.5 dBm
FG-3	50%	-50 dBm	-54.5 dBm
BG	366%	-71 dBm to -78 dBm	-75.5 to -82.5 dBm

Recommended TACAN/DME Systems to Be Tested[35]

DME Interrogators

- **Collins 860E-3** Potentially most susceptible because it was found in UK testing to have range errors from simulated CW signals similar to PMSE.
- **King KDM 7000** because it may have the widest receiver response

[33] NTIA Report SPS WG-1 TR-96-001 entitled, “JTIDS Spectrum Supportability Documentation TACAN/DME Beacons” September 1996.
[34] DME Receiver Environment Taken from: German Armed Forces Technical Test Center for Information Technology and Electronics WTD 81 Document entitled, “German Frequency Clearance for MIDS/JTIDS Peacetime Operations and Its Geographical Area” dated 14 June 2005
[35] Information provided by the Link 16 Spectrum MNWG SASWG to EUROCONTROL Regarding LDACS testing at Meeting in March 2011

- **King KDM-705A** because it was used for the UK PMSE tests
- **DMA 37A scanner** because it was slightly more susceptible than DME 700. The scanner search function may be affected by the presence of an LDACS signal. Multiple scanners should be tested
- **DME 890** because it was among the most susceptible general aviation receivers
- **Cessna 1077B** because it was among the most susceptible general aviation receivers
- **KN-64** because it was used for the UK PMSE tests
- **KN 65** because it represents a unit that uses an analogue range search algorithm

TACAN Interrogators

- **KTU 709 DME** because it was the only non-military unit tested.
- **AN/ARN 118** because it is widely used by Air Force
- **AN/ARN 84** because it is widely used by Navy
- **AN/ARN 153** because it represents a newer design
- European TACAN interrogator types should also be selected such as the one used on the Euro Fighter
- Multiple designs of embedded TACAN units within the JTIDS/MIDS terminals

TACAN/DME Beacons

- **Italy Thales**
  - AN453
- **United Kingdom**
  - Fernau 1117
  - Fernau 2020
  - Butler 1020
- **France Thompson**
  - DME 740
  - DME 721
- **United States**
  - Cardion 9783
  - ITT 9996 TACAN
- **Japan**
  - NEC DME 91A
  - NEC DME-90A

Example SSR/IFF Systems to be Tested and Evaluated with Proposed Link 16 and PMSE environments

SSR, Mode S based and IFF systems and equipment

US: FAA Tech center 1996 prototypes not specified in detail, sliding window detector

UK: Trig Avionics TT21 Class 2 Mode S and 1090ES ADS-B Out Transponder (Note: Standoff distance /frequency separation for no impact to PMSE should also be established)

Recommendations from DFS (GE) for missing systems and equipment:

Interrogator DME DME-40
Newer DME, TACAN transponder not yet accounted e.g. Wilcox, Indra

Interrogator Mode 1 to C: 1990 e.g. IFF Mode 1 to C,
Parrot for Interrogator Mode 1 to C: tbd

Interrogator Mode 1 to 5 incl Mode S: MSSR 2000 (e.g. Bundeswehr)
Parrot for Interrogator Mode 1 to 5, incl Mode S: tbd

Interrogator Mode A, C, S: MSSR 2000 interrogator certified for civil use and procured by ANSP
Parrot for Interrogator Mode A, C, S: tbd

IFF transponder Mode 1 to C Tbd
IFF transponder Mode 1 to 5 Tbd
SSR Transponder Mode A, C tbd
SSR Transponder Mode A, C, S tbd
SSR Transponder Mode A, C, S and Mode S Phase Overlay tbd

ACAS
TCAS

Enhanced surveillance

MLAT (airport and wide area).
Thales MLAT
Saab Sensis MLAT

UAT

GNSS receiver:
EGNOSS receiver
GBAS reference receiver

GNSS supporting GNSS signals in the band 1164-1215 MHz: Repeater