Designation: E2854/E2854M – 21

Standard Test Method for Evaluating Response Robot Radio Communications Line-of-Sight Range[1]

This standard is issued under the fixed designation E2854/E2854M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The robotics community needs ways to measure whether a particular robot is capable of performing specific missions in complex, unstructured, and often hazardous environments. These missions require various combinations of elemental robot capabilities. Each capability can be represented as a test method with an associated apparatus to provide tangible challenges for various mission requirements and performance metrics to communicate results. These test methods can then be combined and sequenced to evaluate essential robot capabilities and remote operator proficiencies necessary to successfully perform intended missions.

The ASTM International Standards Committee on Homeland Security Applications (E54) specifies these standard test methods to facilitate comparisons across different testing locations and dates for diverse robot sizes and configurations. These standards support robot researchers, manufacturers, and user organizations in different ways. Researchers use the standards to understand mission requirements, encourage innovation, and demonstrate break-through capabilities. Manufacturers use the standards to evaluate design decisions, integrate emerging technologies, and harden systems. Emergency responders and soldiers use them to guide purchasing decisions, align deployment expectations, and focus training with standard measures of operator proficiency. Associated usage guides describe how these standards can be applied to support various objectives.

Several suites of standards address these elemental capabilities including maneuvering, mobility, dexterity, sensing, energy, communications, durability, proficiency, autonomy, and logistics. This standard is part of the communications suite of test methods.

1. Scope

1.1 This test method is intended for remotely operated ground robots using radio communications to transmit real-time data between a robot and its remote operator interface. This test method measures the maximum line-of-sight radio communications distance at which a robot can maintain omni-directional steering, speed control, precise stopping, visual acuity, and other functionality. This test method is one of several related radio communication tests that can be used to evaluate overall system capabilities.

1.2 A remote operator is in control of all functionality, so an onboard camera and remote operator display are typically required. Assistive features or autonomous behaviors may improve the effectiveness or efficiency of the overall system.

1.3 Different user communities can set their own thresholds of acceptable performance within this test method to address various mission requirements.

1.4 *Performing Location*—This test method may be performed anywhere the specified apparatuses and environmental conditions can be implemented.

1.5 The International System of Units (a.k.a. SI Units) and U.S. Customary Units (a.k.a. Imperial Units) are used throughout this document. They are not mathematical conversions. Rather, they are approximate equivalents in each system of units to enable the use of readily available materials in different countries. The differences between the stated dimensions in each system of units are insignificant for the purposes of comparing test method results, so each system of units is separately considered standard within this test method.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

[1] This test method is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.09 on Response Robots.

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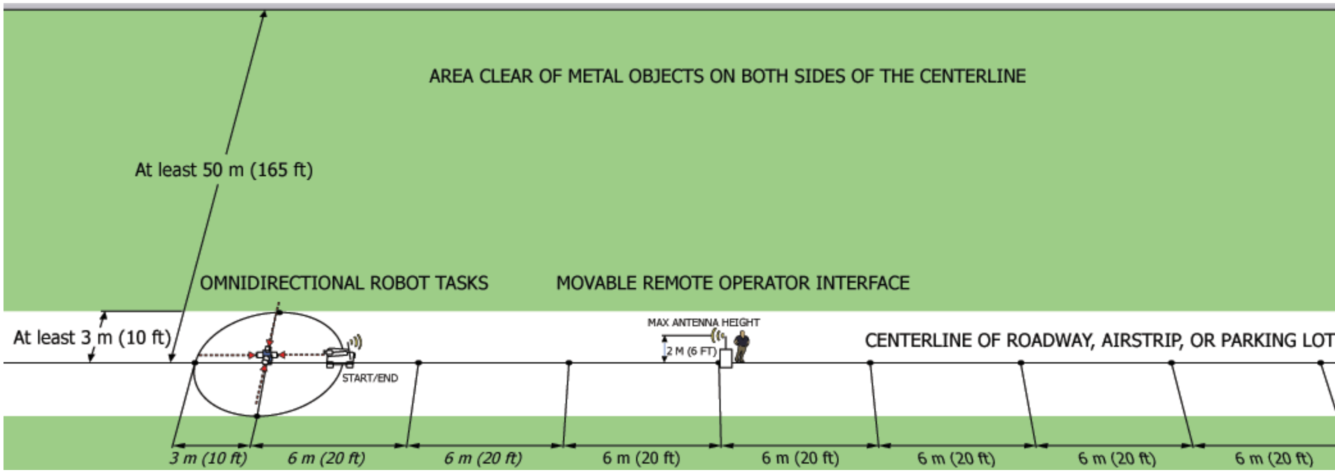

Overview of the test site showing a roadway, airstrip, or parking lot with a centerline and measured incremental distances between the omnidirectional robot tasks and a movable remote operator interface.

FIG. 1 Overview of the Test Site

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2521 Terminology for Evaluating Response Robot Capabilities

E2566 Test Method for Evaluating Response Robot Sensing: Visual Acuity

E2592 Practice for Evaluating Response Robot Capabilities: Logistics: Packaging for Urban Search and Rescue Task Force Equipment Caches

E2855 Test Method for Evaluating Emergency Response Robot Capabilities: Radio Communication: Non-Line-of-Sight Range

2.2 *Other Documents:*

NIST Special Publication 1011-II-1.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I:3[3]

NIST Special Publication 1011-I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I: Terminology, Version 2.04[3]

3. Terminology

3.1 The following terms are used in this test method and are defined in Terminology E2521: *emergency response robot* or *response robot*, *fault condition*, *Landolt C*, *line-of-sight communications*, *non-line-of-sight communications*, *optotype*, and *radio interference*.

3.2 The following terms are used in this test method and are defined in ALFUS Framework Volume I:3: *autonomous*, *autonomy*, *level of autonomy*, *operator control unit (OCU)*, and *semi-autonomous*, and *remote teleoperation*.

4. Summary of Test Method

4.1 This test method is intended for remotely operated ground robots using radio communications to transmit real-time data between a robot and its remote operator interface. This test method specifies robot maneuvering and camera pointing tasks performed from designated standoff distances between the robot and remote operator interface (see Fig. 1). This test method measures the maximum line-of-sight radio communications range at which a robot can complete omnidirectional tasks including continuous steering, speed control, precise stopping, visual acuity, and other functionality. This test method is conducted in an environment with no radio frequency interference and minimal radio propagation effects. The same test can be conducted at any operationally significant environment (with representative radio interference) as a practical measure of line-of-sight radio communications range.

4.2 This test method is conducted on a straight and flat surface at least 6 m [20 ft] wide and longer than the maximum radio communications range of the robotic system being evaluated, or longer than the operationally significant range of the intended application. There must be no obstructions on the paved surface or radio reflective metal objects within 50 m [165 ft] of the centerline to minimize effects from multi-path radio transmissions. A roadway, airstrip, or parking lot can be used depending on the overall length required (see Fig. 2).

4.3 The maneuvering tasks require the robot to straddle and follow a circular path marked on the ground with 3 m [10 ft] radius to demonstrate continuous steering and speed control. The robot also aligns with four perpendicular buckets in the center using a designated forward-facing camera on or over the robot chassis. These tasks require the robot to face four different directions relative to the operator interface to ensure that there are no directionality issues with transmitting or

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov/el/isd/ks/autonomy_levels.cfm.

Left) The robot maneuvering tasks include a circular robot path with 3 m [10 ft] radius for the robot to straddle and follow.
Middle) The center buckets are perpendicular and limit the viewing angles of the interior targets.
Right) Each bucket target has an inscribed ring (shown as green) to evaluate successful alignment along with five increasingly small concentric ring gap orientations to evaluate visual acuity.

FIG. 2 Robot Maneuvering Tasks

receiving communication signals. Each recessed bucket target has an inscribed ring with a limited viewing angle to evaluate successful alignment. A 5-point score records successful completion of the robot maneuvering tasks (see Fig. 3 and Fig. 4).

4.4 The visual acuity tasks require identifying up to five increasingly small concentric ring gap orientations in each bucket. A separate 5-point acuity score per target across four different targets totals 20 points for overall acuity.

4.5 There are four performance metrics to consider when calculating the results of a test trial. They should be considered in the following order of importance: *line-of-sight radio communications range*, *reliability*, *average visual acuity*, and *efficiency*.

4.6 This test method is performed with appropriate safety precautions to mitigate any potentially dangerous robot behaviors due to lost communications. The operator performs the maneuvering and visual acuity tasks from a standoff distance near where loss of either control or video is evident. The test is then repeated closer to the robot along the centerline at incremental distances of 6 m [20 ft] until all omnidirectional maneuvering and visual acuity tasks are performed successfully. The maximum distance from the remote operator interface and its co-located antenna to the center of the circle is considered the maximum line-of-sight radio communications range.

4.7 *Potential Faults Include:*

4.7.1 Any contact by the robot with the apparatus that requires adjustment or repair to return the apparatus to the initial condition.

4.7.2 Any visual, audible, or physical interaction that assists either the robot or the remote operator.

4.7.3 Leaving the apparatus during the trial.

4.8 Test trials shall produce enough successful repetitions to demonstrate the reliability of the system capability or the remote operator proficiency. A complete trial of 10 to 30 repetitions should take 30 to 60 min to complete. When measuring system capabilities, it is important to allow enough time to capture a complete trial with an expert operator. When measuring operator proficiency, it is important to limit the time of the trial so that novice and expert operators are similarly fatigued.

4.9 Various other operationally significant targets can be incorporated into this test method to evaluate color acuity, thermal acuity, audio acuity, latency, signal/packet loss, etc.

5. Significance and Use

5.1 This test method is part of an overall suite of related tests that provide reproducible measures of radio communications for remotely operated robots. It measures the maximum line-of-sight radio communications range between a robot and its remote operator interface using omnidirectional robot maneuvering and visual acuity tasks to evaluate the degradation of essential mission capabilities due to communications latency and loss.

5.2 This test method is inexpensive, easy to fabricate, and simple to conduct so it can be replicated widely. This enables comparisons across various testing locations and dates to determine best-in-class system capabilities and remote operator proficiency.

5.3 *Evaluations*—This test method can be conducted in a controlled environment with no radio frequency interference and minimal radio propagation effects to measure baseline capabilities that can be compared widely across robotic systems. It also can be embedded into any operational training scenario as a practical measure of line-of-sight radio communications range with additional degradation due to uncontrolled variables such as radio frequency interference, weather, etc. The results of these scenario tests can be compared across robotic systems only when conducted in the same environment in similar conditions. However, the results cannot be compared reliably to results from other venues or environmental conditions due to the uncontrolled variables.

5.4 *Procurement*—This test method can be used to identify inherent capability trade-offs in systems, make informed purchasing decisions, and verify performance during acceptance testing. This aligns requirement specifications and user expectations with existing capability limits.