Jamming Techniques and their Usage in Distributed Electronic Warfare Simulation

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ABSTRACT

The Institute of Electrical and Electronics Engineers 1278.1 Distributed Interactive Simulation (DIS) Standard's Electromagnetic Emission Protocol Data Unit contains a Jamming Technique field and the associated jamming techniques are enumerated in SISO-REF-010. There are currently 134 hierarchical jamming techniques listed with no information provided other than their name and location in the hierarchy. This is not enough information to ensure common understanding among Electronic Warfare (EW) subject matter experts and simulation developers to support interoperability, fair fight, and good training. This paper describes an ongoing effort to provide definitions for these techniques, address issues with the hierarchy, and provide additional jamming interaction data that will support higher fidelity simulation.

This effort has two phases. The first phase is to provide concise and unambiguous definitions for all valid jamming techniques. To document jamming technique definitions in an open environment, we cite unclassified and exportable academic and research sources. The jamming technique definitions allow jammer and radar modelers to have a common understanding of the techniques which facilitates fair fight distributed EW between manned simulations, constructive forces, and live assets participating in a training scenario. The jamming technique definitions are proposed for a new annex of the DIS Standard.

The second phase will redesign the hierarchy to properly support interoperability between systems with different levels of fidelity. One of the main reasons for the proposed redesign is that the current hierarchy contains a problematic mixture of jamming system architectures and techniques. This phase will also propose additional attributes that will allow jammer and radar simulations to more efficiently represent more detailed EW interactions. The additional attributes help define the quality of the jamming waveform and will allow higher fidelity simulation of the effects on the victim radar.

All proposed changes will be vetted with the simulation community.

ABOUT THE AUTHORS

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INTRODUCTION

The purpose of this paper is to describe work being done to:

- Provide a common understanding of simulated radar jamming techniques
- Correct problems with the current simulation jamming technique hierarchy
- Provide an enhancement in the fidelity of simulated jamming interactions

This paper describes issues related to jamming techniques and their use in distributed Electronic Warfare (EW) simulation, our two-phased approach to solving the issues, the results and status of the two phases, and finally our conclusions and plans.

We are working under the auspices of the Simulation Interoperability Standards Organization (SISO) Distributed Interactive Simulation / Real-time Platform Reference Federation Object Model (DIS / RPR FOM) Product Support Group (PSG) and the SISO Standards Activity Committee Special Working Group Reference for Enumerations for Simulation (SAC SWG Enumerations).

ISSUES WITH THE CURRENT JAMMING TECHNIQUES AND THEIR USE IN DISTRIBUTED ELECTROMAGNETIC WARFARE SIMULATION

The Institute of Electrical and Electronics Engineers (IEEE) 1278.1 Distributed Interactive Simulation (DIS) Standard's Electromagnetic Emission (EE) Protocol Data Unit (PDU) contains a Jamming Technique field and the associated jamming techniques are in SISO-REF-010. There are currently 134 hierarchical jamming techniques defined only with their name and location in the hierarchy. Several problems lead to assumptions about jamming effectiveness that are not based on a common understanding of EW principles. These problems include ambiguity and lack of definitions, invalid jamming techniques, as well as organizational problems.

NOTE: References to SISO-REF-010 enumerated jamming techniques throughout this paper are followed by the enumeration in parenthesis, e.g., Blinking Spot Noise (1.75.10).

The DIS Jamming Technique field is a four-part enumeration that represents a hierarchy comprised of Kind, Category, Subcategory, and Specific components. In the example below, Kind 1 is Noise, and within the Noise Kind, Category 75 is Spot Noise, and within the Spot Noise Category, Subcategory 10 is Blinking Spot Noise. This portion of the jamming technique hierarchy is illustrated below:

```
1    Noise
…
1.75      Spot Noise
1.75.5         Automatic Spot Noise
1.75.10        Blinking Spot Noise
```

The jamming technique name and enumeration alone are insufficient to support a fair fight within the simulation or common understanding among EW subject matter experts and simulation developers. This results in discrepancies

within a simulation caused by variation in modeling radar susceptibility to jamming, representation of intended effect, and determination of jammer effectiveness. EW fair fight means a specific jammer/radar interaction results in the same or reasonably similar outcome, regardless of simulation systems in use. All simulation systems should have the same basic understanding of jamming effectiveness for specific jammer and victim radar interactions. This ensures that a common engagement does not provide significantly different results from different simulation systems or circumstances. The lack of jamming technique definitions can adversely affect simulated EW fair fight and can result in negative training.

Lack of Authoritative Definitions

The current jamming techniques listed in SISO-REF-010 and utilized in DIS exercises have no clearly defined definitions. After searching and finding authoritative definitions, many remain unpopulated with respect to a quality authoritative definition. Burst Spot Noise (1.75.15) is an example of a jamming technique for which no definition could be found.

Conflicting Definitions

In our search of academic and industry sources we found that different documents sometimes had different definitions for the same jamming technique name. An example is Doppler Noise (1.30). Alternately, different source documents occasionally have different names for the same jamming technique. For example, Sea-Bounced (2.10.35) and Terrain Bounce (2.10.45) represent different use cases, but the underlying jamming technique is the same. A change recommendation for this specific example is presented later in the paper.

Invalid Jamming Techniques

Some of the existing jamming techniques identify specific jammer architectures in lieu of a technique. For example, Transponder (2.65.25) is a jamming system hardware architecture. Transponder, Digital Radio Frequency Memory (DRFM), and Direct Digital Synthesis (DDS) jammers all transmit basic jamming techniques like range gate walk-off or spot noise. The differences between these architectures can be found in system capabilities and waveform artifacts not captured at the level of abstraction found in the current hierarchy. Down Link (2.60) is another example of an invalid jamming technique because it is an exploitation point and not a jamming waveform.

Defective Hierarchy Structure

The jamming technique issues in the current hierarchical list make consistent jamming simulation across different fidelity levels doubtful. The DIS Standard describes the purpose of the jamming technique hierarchy as follows:

> Jamming techniques are arranged in a hierarchical structure such that higher fidelity simulations may depict detailed representations of a technique (such as a combination technique called Range Gate Pull Off and Swept Square Wave). Lower fidelity simulations may depict the same technique in a more generic manner (such as Angle and Gate Stealer or simply Deception). Receiving simulations may "promote" techniques to a less specific level supported by the local radar receiver model. [IEEE Std 1278.1-2012 paragraph 5.7.3.8.a]

Invalid techniques and specific techniques listed in the wrong location within the hierarchy will prevent proper simulation when the model needs to promote (i.e., roll-up) techniques to a less specific level as defined in the DIS Standard. For example, Skirt Frequency (1.75.25) is in the Noise category but is not a noise technique. Skirt Frequency Definition: Jamming on the skirts of the frequency response curve of the victim radar receiver. Skirt jamming effectiveness depends on unbalance between the sum and difference channels of the victim radar receiver at these frequencies where rapid phase shifts are present in each channel. This technique can produce instability in angle tracking for radars where signal phase is important [Applied ECM, Volume 1, page 843]. A simplified simulation rolling-up Skirt Frequency (1.75.25) one level would get Spot Noise (1.75), a very different jamming technique. A roll-up of Skirt Frequency (1.75.25) to Spot Noise (1.75) would change the jamming effect from instability in angle tracking, to range obscuration, a very different effect which could alter the outcome of the simulated engagement. Similarly, if there are no definitions of the jamming techniques, different radar simulation modelers will make

assumptions in isolation, most likely with different results, creating discrepancies in the distributed electronic warfare simulation environment that does not give the same results for the same interactions between different federates.

A TWO-PHASED APPROACH

This is a two-phased effort. In Phase 1 we identify the jamming technique issues and recommend solutions within the existing hierarchy. In Phase 2 we introduce enhancements for the jamming technique hierarchy and additional protocol information to improve the fidelity of simulated electronic warfare engagements.

As we executed this effort, Phase 1 and Phase 2 have overlapped. It is still useful to describe the effort and results in terms of these phases, even if they are not sequential and independent as originally planned.

PHASE 1: JAMMING TECHNIQUE DEFINITIONS AND DEPRECATIONS

The current hierarchy contains a problematic mixture of naming conventions that includes jamming system architectures, victim exploitation points, descriptions of jammer waveforms and/or intended effects, and engineering terms at each level of abstraction. We began Phase 1 by searching academic and authoritative industry publications for a concise unambiguous definition for each technique in the existing hierarchy to provide a common understanding of simulated radar jamming techniques. Many techniques were not found in the reference sources or had definitions that conflicted with their location in the hierarchy. These techniques are flagged for deprecation and replacements suggested where discrepancies in the hierarchy were identified.

The objective of Phase 1 is to provide concise unambiguous definitions of the transmitted jamming waveform. The jamming technique definitions allow jammer and radar modelers to have a common understanding of a jamming technique, providing a baseline of jamming effectiveness.

This effort provides the simulation community with:

- A validated list of jamming technique enumerations, including additions and deprecations
- Jamming technique definitions for each valid enumeration, unique to the one jamming technique name, used to describe the transmitted jamming waveform
- Source references for each jamming technique definition
- Documented rationale for all proposed changes including any jamming technique depreciations

Jamming Technique Definitions

The rationale for our methodology is to support the entire simulation community, so open literature (unclassified, accessible to all users) must be used as a source of this information. Jamming technique definitions are taken from authoritative open literature. Authoritative sources are technical books used for reference in the industry, published academic papers, or technical books used for teaching at the university level. The literature must be unclassified and available to all users. We take jamming technique definitions verbatim from authoritative sources except where the authoritative source has "also called" or "also known as" and another jamming technique name, that additional jamming technique name text is omitted. Jamming technique definitions do not determine jamming effectiveness; they are to describe a waveform. Source literature used in this effort is listed in the references section at the end of this paper.

The jamming technique definitions should unambiguously describe the transmitted jamming waveform at a level of detail that provides a common understanding to EW subject matter experts and simulation developers. Ideally, the combination of technique definition and EE PDU should provide sufficient detail for EW subject matter experts and simulation developers to produce a radar model capable of making a jamming susceptibility decision, applying jammer effects, and simulating a level of jammer effectiveness appropriate for the available information.

A common understanding of jamming techniques allows simulated radar modelers to model jamming effectiveness consistently between federates. This should provide a consistent fair fight simulation of jamming effectiveness

regardless of where the simulated jammer or simulated victim radar resides. This will allow simulated electronic warfare engagements to happen more accurately and consistently across training exercises. The plan is for a new DIS Standard annex to contain the jamming technique definitions for each valid jamming technique, as illustrated by the following examples:

Pseudorandom Amplitude Modulation (1.50)
Definition: The Pseudorandom Amplitude Modulation jamming technique consists of square wave modulating the output signal of an ECM set, such that the frequency of the square wave is controlled by a pseudo-random function that contains the frequencies of the scan frequencies of the victim radar.

Range Bin Masking (1.65)
Definition: In Range Bin Masking, rather than using noise to mask the echo signal, copies of the radar pulse are transmitted by the jammer before and after the received radar pulse.

Swept Amplitude Modulation (1.80.10)
Definition: This is a common self-screening technique that is produced by amplitude modulating the output signal of an ECM set with a square or rectangular wave that sweeps in frequency through the expected scan frequency range of a conical-scan tracking radar.

Jamming Technique Deprecations

When no valid jamming technique definition is found in an authoritative source, the jamming technique is recommended for deprecation. Examples of jamming technique deprecation include:

- Jamming technique names that are actually jammer hardware architectures, not a name of a jamming technique transmitted waveform. Transponder (2.65.25) is a jamming system hardware architecture, not a definition of a jamming technique transmitted waveform. Transponder jammers, Digital Radio Frequency Memory (DRFM) architecture jammer, and Direct Digital Synthesis (DDS) architecture jammers can all create jamming, like range gate walk-off, but they are jammer architectures with different capabilities, not techniques. Transponder (2.65.25) is not a valid jamming technique and is recommended for deprecation.
- Different source documents occasionally have different definitions for the same jamming technique name, for example Doppler noise.
- Some of the existing jamming technique names are not in authoritative technical literature, no good definition of the jamming technique waveform is available.
  - o Click jamming has a definition but the definition is from the "Space and Electronic Warfare Lexicon" web site; not an authoritative source by our definition.
  - o Bistatic Clutter (1.15), Definition: A jamming technique that exploits ground clutter in the vicinity of the victim radar. High power, generally continuous wave, generated by the jammer is reflected from multiple points and enters the radar receiver through its antenna side lobes and back lobe. The only definition we could find is from a web page "Space & Electronic Warfare Lexicon Terms".
  - o Some of the existing jamming technique names are not found in any authoritative source, for example, Burst Spot Noise (1.75.15).
- Some of the existing jamming technique names are exploitation points.
  - o Down Link jamming (2.60) Jamming power enters the downlink receiver at the radar site, not the target tracking radar receiver. The actual downlink jamming could be a deception or a noise technique.
- Some of the existing combination jamming technique names are not valid combinations. Combination jamming techniques should not be created from jamming techniques from different levels of fidelity (different levels of the hierarchy) are not allowed, for example Combining kind with category - Noise (1) and Angle (2.10) should not be used. Combining techniques that both use the same transmitted waveform characteristics is not allowed, a jammer cannot transmit both of those waveforms with one transmit channel. For example, Velocity Gate Walk-off and velocity false targets, both use highly controlled frequency modulation in different ways.

In the context of SISO-REF-010, deprecation is an attribute of an enumeration that indicates the enumeration is obsolete and possibly superseded by another entry. The deprecated enumeration is not deleted nor is it reused, thus

preventing enumeration conflicts. When a deprecated enumeration is superseded a reference to the recommended enumeration is provided. A deprecated enumeration can still be used with the understanding that it's use is no longer recommended by the simulation community. In this effort we are identifying enumerations that are questionable or invalid jamming techniques and will be recommending their deprecation to the SISO enumerations working group.

Once vetted and approved, SISO-REF-010 will reflect revised jamming technique names and deprecations as shown in the notional example below:

1   Noise
1.5   Amplitude Modulation Noise
1.10   Barrage Noise
1.10.5   Click
1.10.10   Source Noise (deprecated)
1.15   Bistatic Clutter

PHASE 1 STATUS

There are currently 134 jamming techniques listed in SISO-REF-010. During Phase 1 we have methodically researched available references for unclassified authoritative definitions for the techniques. Many of the jamming techniques are combinations of other techniques. As Phase 1 and Phase 2 intersected, we concluded and recommend the deprecation of all of the combination techniques, as shown in Table 1 below.

Table 1. Phase 1 Jamming Technique Definition Status

Jamming Technique Kind	Definition w/ Source Identified	Definition w/ Source TBD	Significant Issue(s)	Recommend Deprecation	Total
Noise	18	3	0	9	**30**
Deception	17	3	8	53	**81**
Deception and Noise	0	0	0	21	**21**
Special	2	0	0	0	**2**
Total	**37**	**6**	**8**	**83**	**134**

There are currently 37 jamming techniques with authoritative definitions identified, and 83 jamming techniques that are recommended for deprecation. Combined, that's a total of 120 jamming techniques, or 90%. There are a handful of jamming techniques that we have yet to find a good authoritative definition for, and another handful of jamming techniques that have significant issues that still need to be resolved.

The 83 jamming techniques that are recommended for deprecation include the entirety of the Deception and Noise (combination) techniques (21) and all of the other combination techniques (27), as well as the following non-combination jamming techniques: Source Noise (1.10.10), Partial Band (1.45), Pulse Noise (1.55), Repeater Noise (1.70), Narrowband Repeater Noise (1.70.5), Wide Band Repeater Noise (1.70.10), Burst Spot Noise (1.75.15), Doppler Spot Noise (1.75.20), Frequency Swept (1.80.5), Analyzer (2.5), Sea-Bounced (2.10.35), Terrain Bounce (2.10.45), Colinear (2.45), Double Cross (2.55), False Doppler Target (2.65.10), Transponder (2.65.25), Chirp Gate Stealer (2.75.5), Glint Enhance (2.85), Jittered Pulse Width (2.100), Pulse (2.110), Repeater and all of its children (2.130 through 2.130.35), Scintillation (2.135), and Serrodyne (2.140). These recommended deprecations are being listed explicitly to raise awareness, promote discussion within the simulation community, and determine if there are any objections. Because of the sensitive nature of this topic when associated with a particular platform, device, or program, it is often difficult to obtain feedback. The community is encouraged to provide references to open, unclassified, and non-export controlled information such as books, articles, and papers that might provide a definition of a jamming technique that is otherwise undefined. Techniques that remain in this status will be recommended for deprecation.

For the specific case of Sea-Bounced (2.10.35) and Terrain Bounce (2.10.45) in the current hierarchy, we recommend both of them be deprecated and replaced by a new jamming technique: Bounce (2.10.50).

PHASE 2: ENHANCEMENTS TO THE JAMMING TECHNIQUE HIERACHY AND EW DISTRIBUTED SIMULATION INTERACTIONS

Phase 2 addresses improvements to the jamming technique hierarchy, specification of multiple jamming techniques in the simulation protocol, and representation of the quality of the jammer waveform.

Improved Jamming Technique Hierarchy

The purpose of the jamming technique hierarchy is to manage complexity and level of detail by providing a mechanism to determine a higher level of abstraction, i.e., "rolling up" in the hierarchy, when sufficient detail is not available or not required for a specific jamming technique in the receiving simulation system. The roll-up hierarchy supports interoperability between systems with different training requirements and/or different levels of fidelity.

The jamming technique definitions are proposed for a new annex of DIS. Phase 2 adds a proposal to redesign the hierarchy to properly support the roll-up concept. The plan is to deprecate the entire list of original jamming techniques and add a new list using a new hierarchy. Valid techniques from the original list will be placed in the new hierarchy where appropriate.

The new hierarchy starts at Kind 10. At the highest level there will be Kind 10, 20, 30, etc. All of the jamming techniques defined for the new hierarchy will be defined in this new area, for example, 10.x.x.x, 20.x.x.x. We then deprecate all of the existing jamming techniques in Kind 1 (Noise), 2 (Deception), 3 (Deception and Noise), and Kind 4 (Special). Table 2 provides a high-level comparison of the old and new proposed jamming technique hierarchies. More details on the new proposed hierarchy will follow later in the paper.

Table 2. Old vs. New Jamming Technique Hierarchy: Kind and Category

Old	New
1 Noise	10 Obscuration
1.xx (17 Categories)	10.10 Obscuration By Noise
2 Deception	10.20 Obscuration by Continuous Wave
2.xx (30 Categories)	20 Deception
3 Deception and Noise	20.10 Range Deception
3.xx (6 Categories)	20.20 Velocity Deception
4 Special	20.30 Angle Deception
4.1 Super Jam	20.40 Multiple False Targets
	30 Special
	30.10 Super Jam

The enumeration values in the new hierarchy are incremented by 10 to allow room for future growth between existing values. Starting the new hierarchy at 10 provides for a clean separation between old and new while supporting migrations, translations, and gateways as necessary for interoperability between simulation systems operating with the old and the new hierarchies.

As a result of our research and analysis, the new hierarchy does not include any built-in combinations. This will be addressed later in the paper.

All of the valid jamming techniques we reviewed and defined in Phase 1 can be brought over and placed in the new hierarchy wherever they make sense with respect to the new hierarchy, and their definitions come with them. All of the jamming technique definitions correlate to their location in the new hierarchy. All of the work done in Phase 1 will persist in the new and improved hierarchy.

This will allow for a clean migration path and road forward. Simulations and federations that are satisfied with their current implementations can continue using the original jamming techniques in Kind 1..4, even if they have been deprecated. Simulations and federations that want to mix and match can do that. Simulations and federations that want to take the leap to the new and improved hierarchy can do that, if and when they are ready. Having the new hierarchy separated by the new Kind enumerations will make it simple and easy for the simulations to know immediately if they are receiving old vs. new jamming techniques and they can be implemented to deal with one or the other or both. Gateways can also be used to translate between the two to the extent that simulations/federations may wish to do so.

A notional revised jamming technique hierarchy is shown in Figure 1 below. To properly support jamming technique roll-up, the same levels of jamming technique fidelity should be at the same levels in the hierarchy. Each successive level provides additional fidelity. At the highest level (Kind), the general intended effect is represented. At the Category level, more detail regarding how the intended effect is achieved is represented. Next, the Subcategory level provides additional amplifying information, and so on. This principle will be maintained as the revised hierarchy is further developed. The revised hierarchy will be vetted with the simulation community, including the SISO DIS and enumerations working groups.
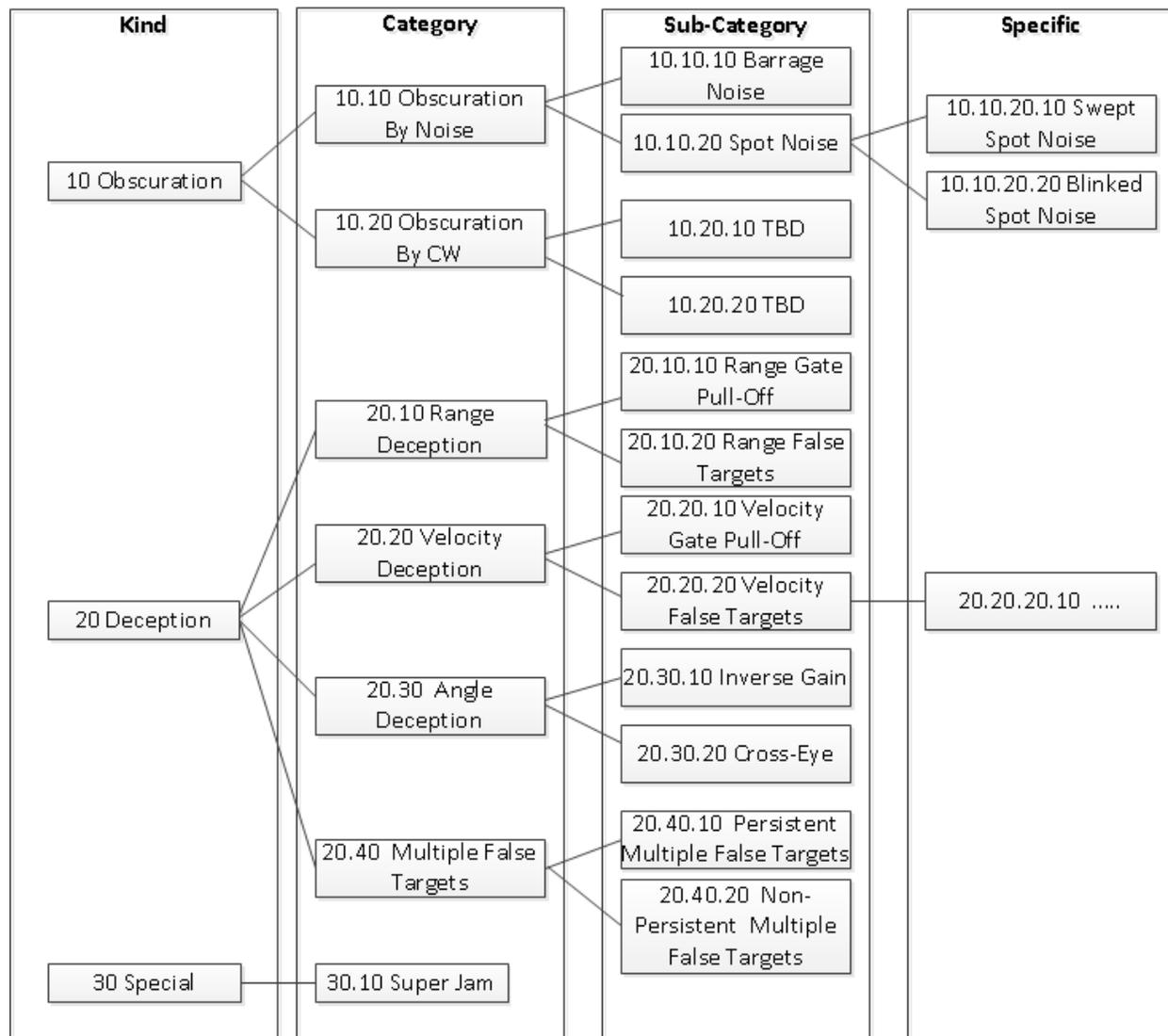

Figure 1. Notional Revised Jamming Technique Hierarchy

Combination Techniques

One of the significant problems with the existing hierarchy is the representation of jamming techniques that are a combination of other techniques. In the original hierarchy, this was done in different ways. The first method was to create an entire Kind for Deception and Noise (3) combinations, and then Categories within that Kind, and so forth. An example would be the Angle and Spot (3.20) Category, which then has multiple Subcategories, one of them being Inverse Gain and Spot Noise (3.20.10). The second method was a little more ad-hoc, for example, to create a Category such as Angle and Gate Stealer (2.15) within the Deception (2) Kind and then create Subcategories of specific combinations such as Inverse Gain and RGPO (Range Gate Pull-Off) (2.15.20). In both cases, these combination techniques proved to be problematic in terms of mismatched levels, naming convention and hierarchy issues, and even references to techniques that are not elsewhere defined in the hierarchy. Moreover, the hierarchy becomes a limiting factor when attempting to represent combinations that are not predefined.

Instead of defining enumerated techniques that are combinations of other techniques, Phase 2 recommends changing the Electromagnetic Emission (EE) PDU to allow multiple individual techniques to be associated with any given jammer beam transmission. This provides a better mechanism for creating combinations of jamming techniques.

Using the current jamming technique hierarchy and EE PDU, a jammer transmitting jamming techniques of range gate pull-off and velocity gate pull-off would be represented using the combined jamming technique RGPO and VGPO (2.75.15). Using the revised jamming technique hierarchy and the proposed enhancement of the EE PDU, this same combination of jamming techniques would be represented as a jammer beam with multiple jamming techniques: Range Gate Pull-Off (20.10.10) and Velocity Gate Pull-Off (20.20.10).

There will be general guidance to prevent unrealistic jamming technique combinations, such as:

- Combining incompatible levels of fidelity (i.e., different levels of the hierarchy) is *not allowed*, for example
  - Combining jamming techniques at the Kind level and Category level, such as Obscuration (10) and Angle Deception (20.30)
  - Combining jamming techniques at the Category level and Subcategory level, such as Angle Deception (20.30) and Spot Noise (10.10.20)
- Combining techniques that use the same transmitted waveform characteristics is *not allowed* because a jammer cannot transmit these waveforms on the same transmit channel, for example
  - Velocity Gate Pull-Off (20.20.10) and Velocity False Targets (20.20.20) both use highly controlled frequency modulation but in different ways

The benefits of this approach are that it makes the hierarchy much simpler, and at the same time it provides greater flexibility to represent combinations of jamming techniques without a rigid and predefined set of allowed combinations, and it supports combinations with a varying number of jamming techniques (e.g., two, three, four or more simultaneous jamming techniques). This flexibility along with the guidelines above provide a better modeling and simulation paradigm that is more in line with real-world EW principles.

Jamming Quality Attributes

Advanced radar signal processors analyze all signal returns, and may differentiate between target reflections and jamming signals based on characteristics of the respective waveforms. If the jammer signal is not realistic for scintillation, coordination of Doppler and range, phase characteristics, and modulation from rotating parts of the target, the signal processor of a modern radar may be able to reject the jamming signal. Conversely, earlier radar receivers may not have the signal processing components necessary to discriminate between jamming and the target reflections. The addition of jammer quality attribute data in the simulation protocol supports improved radar susceptibility determination. A Jammer Architecture enumeration is recommended for inclusion in the DIS protocol as defined below.

Jammer Architecture

Value	Description
0	Other
10	Transponder
20	Analog Repeater
30	Digital Radio Frequency Memory (DRFM)
40	Direct Digital Synthesis (DDS)

This provides a mechanism to communicate jammer information to the victim radar model at a level of abstraction that matches the DIS simulation protocol. A radar model that receives the jammer architecture type is able to use it in the susceptibility decision.

In addition to the Jammer Architecture field, several new jammer quality attributes are being considered to improve the radar susceptibility determination:

- *Persistent*: A flag that represents whether the jamming technique is persistent over time. For example, when a jammer is generating multiple false targets, this flag would indicate whether the targets are random, or if they are persistent with corresponding location and velocity behavior over time. NOTE: The notional revised hierarchy in Figure 1 depicts explicit jamming techniques for Persistent Multiple False Targets (20.40.10) and Non-Persistent Multiple False Targets (20.40.20). These approaches require further evaluation.
- *Constant Gain or Constant Power*: A flag that represents whether the jamming technique is transmitted with constant gain or constant power over time. This attribute is commonly associated with deception techniques from modern jammers.
- *Coordinated*: A flag that represents whether multiple jamming techniques are coordinated. For example, coordinated range and velocity false targets.
- *Cooperative*: A flag that indicates when a jamming technique is being deployed cooperatively with another jamming system. For example, two jammers on separate platforms cooperatively using blinked noise.
- *Coherent*: A flag that indicates when a jammer is maintaining consistent spatial and temporal phase relationships between the victim radar signal received by the jammer and the resulting jamming waveform.

These new constructs will be proposed to the DIS working group for inclusion in the next version of DIS.

Phase 2 Status

Phase 2 status is more difficult to quantify than Phase 1, but has already yielded significant results. From the onset, there were suspicions that the jamming technique hierarchy needed an overhaul. After methodically attempting to research and identify authoritative definitions for the existing jamming techniques that fit within the context of the current hierarchy, it became more and more clear that an overhaul was necessary.

The new hierarchy represented notionally in Figure 1 is incomplete in detail. However, the first two levels (Kind and Category) are considered to be complete and should provide a solid foundation for the remaining Subcategory and Specific details that are yet to be fleshed out. The plan that has been devised to deprecate the current hierarchy and add new enumerations for the revised hierarchy is also complete and should provide a workable migration path and ability to interoperate with gateways as necessary for simulation systems and federations that need to support both paradigms as an interim measure.

Likewise, for the simulation protocol, it is fortunate that the SISO DIS working group is in the process of redesigning all of the PDUs to include the EE PDU, and also defining new capabilities for the DIS PDUs that support flexibility. This will provide a good opportunity to introduce the new concepts being developed for multiple jamming techniques and the new jammer quality attributes that are under consideration.

CONCLUSIONS AND PLANS

This effort started with a simple goal of documenting and providing definitions for the existing jamming techniques. Over time it morphed into also providing protocol enhancements. Documenting and providing jamming technique definitions will provide a common understanding of simulated jamming for all SISO and IEEE standards users. Later we reached the conclusion that the jamming technique hierarchy required an overhaul.

The initial conclusions are to replace the existing jamming technique hierarchy as defined notionally in Figure 1, and with that to deprecate the original jamming techniques in total. The new hierarchy still needs to be fully developed and will include valid techniques from the original list. This will allow simulations of varying fidelities to promote (i.e., roll-up) jamming techniques as defined in IEEE Std 1278.1-2012 paragraph 5.7.3.8.a. We also concluded that the hierarchy should not include built-in combinations, but rather the DIS protocol should be changed to support multiple jamming techniques. This will provide the flexibility for simulations to transmit jamming Electromagnetic Emission PDUs as their systems would operate, not based on a preset list of combinations. Finally, we concluded that a jammer architecture field should be added to the protocol, as well as additional jammer quality attributes. The jammer architecture field and jammer quality attributes provide more information to the simulated radars targeted by jamming to make decisions on jamming susceptibility and effectiveness.

This effort is still in progress. All proposed changes will be vetted with the simulation community through the appropriate working groups and processes. SISO PCR 253 Jamming Technique Descriptions will be updated with the final jamming technique definitions and change requests for the hierarchy and PDU changes will be submitted for consideration for future versions of the SISO and IEEE standards.

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