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Conformity Assessment of Policy-Based Adaptive Radio Systems

by Stephen Berger
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Policy-Based Adaptive Radio (PBAR) systems implementing Dynamic, Adaptive Spectrum Management (DASM) will bring new challenges to regulators who must qualify and manage them. Conformity assessment is the process by which a product or system is confirmed as meeting requirements. Regulatory agencies are required to protect some public interest. They protect the public interest by using an assessment system to assure that a product or service meets a set of defined requirements. Typically these conformity assessment systems are implemented using ISO guidelines, with appropriate adaptations to the needs of the agency. PBAR and DASM bring formidable challenge to the regulator responsible for qualifying them.

The technological innovation and flexibility of policy-based adaptive radio systems present particular challenges. Due to their dynamic and adaptive nature, design qualification (often called type acceptance) will be based on a probability of compliance rather than a fixed and proven determination. There are simply too many variables and potential operating states to measure the response to all possible scenarios and conditions. The full matrix of possible test conditions will have to be reduced to a sparse but testable matrix. Further, new tools for evaluation, field surveillance and field management will be required to assure that the public interest is protected from misuse of the adaptability of these new technologies.

DASM introduces new variable to spectrum management to allow more devices to share the same spectrum. The benefit of increased spectral efficiency is enormous. However, every additional variable adds exponentially to the possible tests to be performed. Each additional variable adds a new dimension and the number of possible conditions to test is increased in a combinatorial fashion. Managing the exponentially increasing number of possible test cases is the challenge that must be addressed by the assessment system evaluating these new systems.

This article reviews the system, per the ISO guidelines, identifies the requirements with their attending challenges and suggests possible approaches for a robust conformity assessment system.

All regulators and other authorities responsible for system operation implement some kind of conformity assessment system (CAS). Typically these systems follow ISO guidelines, making appropriate modifications for the needs of the agency, industry and technology being dealt with. This article begins by reviewing the elements common to conformity assessment systems. It then explores application of CAS to dynamic, adaptive spectrum management systems, particularly policy-based adaptive radio (PBAR) systems.[1]

After a general outline of a CAS is described the similarities and differences between current systems and a CAS for PBAR are reviewed, and challenges are identified.

Where appropriate, use of existing methods is assumed. The discussion here will highlight areas that are new or relatively unique, and particularly those where fundamental shifts in approach may be required to implement a successful system.

Terms

For brevity, the following abbreviations will be used in this article:

CAS (Conformity Assessment System): A system designed to provide assurance that a product or service complies with specified standards and normative specifications.

PBAR (Policy-Based Adaptive Radio): A radio that is governed by a predetermined sets of rules for behavior that are independent of the radio implementation regardless of whether the implementation is in hardware or software and both senses and adapts to its environment. The rules define the operating limits of such a radio. The definition and implementation of these rules can be:

- During manufacture or reconfiguration;
- During configuration of a device by the user or service provider;
- During over-the-air provisioning; and/or
- By over-the-air or other real-time control. (IEEE P1900.1 draft)

Dynamic Spectrum Allocation: The near-real-time reallocation of spectrum resources in response to changing circumstances, including changes of the radio's state (operational mode, battery life, location, etc.), changes in environmental/external constraints (spectrum, propagation, operational policies, etc.), and/or in response to a received command. (IEEE P1900.1 draft)

Adaptive Radio: A radio that adjusts its operation on a near-real-time basis to meet application needs in accordance with changing circumstances, including changes of the radio's state (operational mode, battery life, location, etc.), changes in environmental/external constraints (spectrum, propagation, operational policies, etc.), and/or in response to a received command. (IEEE P1900.1 draft)

DASM (Dynamic, Adaptive Spectrum Management): A system of spectrum management that implements dynamic spectrum allocation using adaptive radios.

Metrology: The science of measurement for determination of conformance to technical requirements, including the development of standards and systems for absolute and relative measurements. (IEEE Dictionary, 1988 edition)

Conformity Assessment Systems

Most regulatory structures conform to the guidelines of ISO 17011[2] in designing conformity assessment systems.[3] Therefore this paper assumes that policy-based adaptive radio (PBAR) systems will be required to comply with regulations structured under the guidance provided in ISO 17011[4] and its companion documents. Hence, to receive regulatory approval some key questions must be satisfactorily answered before these systems will be permitted. Among these questions are:

1. What are the requirements for a minimal acceptable system, and how is that assessment to be made?

2. Are the testing lab/testers/lab assessors qualified to effectively evaluate designs?

3. Will the vendor deliver units within manufacturing tolerances to those evaluated? What process must be implemented in their quality and change control systems for vendors to have adequate control of their production?

4. How will regulatory officials know if non-compliant units are deployed and what corrective actions can be taken if interference problems arise?

5. Are there adequate safeguards that the systems will be used as intended?

In order to provide satisfactory answers to these questions, most CAS contain the following elements:

- Type Testing / Design Evaluation
- Assessment of the Supplier's Quality and Change Management System
- Field Surveillance
- Field Management / Enforcement
- Training of Personnel & ongoing communication with stakeholders

- User Outreach

In order to assist in the design and management of CAS systems, a number of international standards and guidelines have been developed. These documents are intended to encourage a degree of uniformity between different systems and international harmonization of requirements among regulatory authorities. There are many good reasons for this to be done, including elimination of duplicative testing to similar but different regulatory requirements, allowing single qualification for multiple markets. There are economies to be gained when the same or a similar compliance evaluation can be used by multiple agencies in different countries. For these reasons, there is significant similarity in CAS around the world. However, forces toward differentiation assure that there are also significant variation. The forces pressing for harmonization of CAS requirements are in ongoing tension with those moving for differentiation of these same systems. Nevertheless, especially for mobile radio devices, the trend for harmonized requirements is strong.

One of the primary tools utilized to promote harmonization is the international consensus standards process. Various bodies develop standards for new technology areas in an open, consensus process. When multiple regulatory agencies then adopt the same standards, harmonization of regulations internationally is significantly advanced. The IEEE 1900 series of standards has been initiated to serve this function for PBAR systems.

Several types of certification systems exist:

- Some comprise type testing only. These systems assume that if the design is compliant, as represented by a typical device submitted for evaluation, then the deployed units will also be in compliance.

- Other systems include initial testing and field surveillance. In these systems, regulatory resources are focused on initial design evaluation supported by enforcement actions where non-compliance is identified. Quality and change control are left to the discretion of the manufacturer.

- Still other systems include initial testing of a product and assessment of its suppliers' quality systems, followed by routine audits that take into account the factory quality system and the testing of samples from the factory and the open market.

No single system is right for all product types and all purposes. Each application will adopt a specific implementation based on the history, needs, and resources of the regulatory authority, along with its assessment of the consequences of non-conformity. An agency is likely to implement a very stringent system if the consequences of non-conformity could be catastrophic. Alternately where consequences are less severe, especially if addressing non-compliance over time is acceptable, then more permissive systems may be employed.

Design Verification

Most radio transmitters are currently qualified for regulatory certification based on a set of complex but definitive engineering tests. Such an approach is ineffective when evaluating a PBAR for compliance in a DASM system. The device is simply adaptive and capable of operating in too many different states to test them all. Further, its evaluation will be based on a complete device; however the power of PBAR devices is that they combine three components that may be independently updated or modified. A PBAR has a hardware radio, controlled by software which is in turn operated under the constraints of a policy set. Any testing of a final device will have a specific combination of hardware, software and policies. However, the design of PBAR systems is dependent on being able to update these components, particularly the policy set, independently. New approaches to design verification would seem to be needed.

Within the IEEE 1900 series of standards, IEEE Project 1900.3 seeks to establish a means of qualifying software modules intended for use in PBAR devices, independent of the hardware. IEEE P1900.3 proposes to develop an evaluation regiment which would demonstrate that the candidate software module would not command its host device to enter into a disallowed state. IEEE P1900.3 does not propose that such testing is sufficient to qualify a final device. However, should a software module fail an evaluation and be found to, under some condition, instruct a host to transmit in a disallowed manner, there is no reason to go further. Clearly, unless the software module can pass an evaluation, that module in an actual radio could not pass a qualification test.

A particular challenge of testing the software is the need of providing a means for proving the independence and completeness of the software evaluated. PBAR devices, like other wireless devices, are certainly going to be hosts to a broad arrange of applications and features. Certainly it would be counterproductive if a device had to be re-certified every time one of the games on it was modified. However, to allow freedom to modify other applications and features will require strong assurances and safeguards that the radio control software is complete, independent and protected from all other software on the host device.

Some radios even utilize operating systems with application modules performing diverse functions, from radio control to user applications, even games and entertainment. In such an architecture, even knowing what functions potentially influence the radio operation is a significant challenge. Even more daunting is proving that an application or module will and can never influence the radio operation.

Another issue is how to test the many possible scenarios that a PBAR may encounter as it senses its RF environment and adopts its operation to its environment. Physically creating and testing a device in the many different RF environments is both difficult and time consuming. New types of instrumentation make the challenge somewhat less difficult but the root challenge remains.

One proposal is to require that, when a candidate device is submitted for evaluation, a simulation model of the device also be submitted. Using modern simulation tools, the model of the device may be stressed within a wide variety of environments. Physical testing could be reduced to a smaller set of tests, with the primary goal of validating the accuracy of the model.

Possibly the best qualification regiment for these devices would be a carefully constructed combination of physical device testing, software qualification and simulation.

In reality all evaluations are probabilities. Every test has a measurement uncertainty and degree of test-to-test and lab-to-lab repeatability. However, the degree of flexibility and adaptability of PBAR devices will materially heighten the degree to which the final evaluation is, in the end, a probability of compliance. How much certainty is sufficient to issue an equipment grant? The problem is very similar to evaluating product line quality. The only way to have 100% certainty is to test 100% of the production line. Even then it may be argued that 100% certainty is not provided, as test-to-test repeatability may allow a passing device to fail on retest. For production line testing, samples that provide statistically satisfying qualification of a production line has been long accepted. In the EMC arena, international standards give guidance that a sample sufficient to demonstrate that 80% of a production line is compliant 80% of the time is sufficient.[5]

The probabilistic nature of PBAR evaluations is increased by the need to move from avoiding interference to managing interference within acceptable levels. In days gone by it, was possible to build in enough margin so that there was no significant chance of interference from a compliant system. However, as spectrum becomes increasingly scarce and DASM systems are used to increase efficiency, they will be designed to manage systems to an acceptable level of interference. Whether the systems are ultimately designed to give 80%, 90% or 99.999% confidence that interference will not occur, the number will not be 100% confidence. Hence the final conclusion of PBAR qualification is likely to be “the evaluation of this system concludes that 80% of the units produced will cause less than 2% interference 80% of the time.”

In a parallel fashion, qualification of PBAR devices will be based upon a sampling of their possible operating states. These states can and should be intelligently selected. Perhaps a combination of engineering analysis aided by simulation results could narrow the actual testing to a manageable number of tests focused on the most vulnerable or most critical operating states.

Properly constructed, an evaluation combining component testing of hardware and software, simulation and physical device testing could deliver high confidence that the device is in compliance with the requirements of the DASM system.

In reality, the probabilistic nature of an evaluation is not new. However, the degree to which PBAR evaluations are probabilities will take some getting used to.

Qualification Regiment

New technologies call for new test methodologies. With PBAR systems, physical testing presents particular challenges due to the dynamic and adaptive nature of these systems. However, standardized test methods must be available to provide adequate evidence that system designs meet specifications and can be relied upon to operate within regulatory boundaries. It may be argued that regulators will be prevented from allowing such systems without such a qualification regiment because they will not be able to adequately prove such systems will operate as specified.

Key characteristics of a qualification regiment for PBAR systems are:

- **Abstracted Evaluation** – The interaction of real systems to must be abstracted into an evaluation regiment that has a satisfactory predictive correlation to the interactions between real systems. Trials using real systems will be essential in research and for proof of concept trials of PBAR systems. However engineering development and regulatory qualification will require an abstracted evaluation methodology.

- **Diverse Spectral Presentations** – Because PBAR systems are designed to sense and respond to their RF environment, it is necessary to present the system with a diverse set of spectral environments and evaluate the PBAR system response. While it will be necessary to develop a full matrix of RF environments and scenarios, such a matrix will be far too full to test completely. A sparse matrix will be necessary. That sparse matrix must be defensible as adequately surveying the full population of possible operating environments PBAR devices will face when operating in a DASM spectrum scheme.

- **Multiple Variables** – The qualification regiment for PBAR device must be capable of manipulating the variables used by the DASM system. As all DASM systems manage both time and frequency, these qualification regiments must be able to present scenarios controlled for both time and frequency. They must also monitor the PBAR device’s response in time and frequency.

- **Statistical Results** – DASM systems are inherently statistical. Accordingly, evaluation of PBAR devices will be inherently statistical. Regulatory testing for compliance with DASM system requirements will seek to provide assurance that the candidate device will never enter a disallowed state. However, given the infinite number of spectral presentations that may exercise different logic paths in the device, complete testing using all possibilities is not possible. What is possible is to perform sufficient testing so as to provide a high degree of statistical confidence that a candidate system will behave appropriately.

  In optimizing system design, statistical evaluation will be even more important. It is unlikely that competing implementation possibilities will present uniform comparisons. Each implementation is likely to have its own strengths and weaknesses. Choosing the best system will be a process of selecting the system that presents the best overall performance. Having evaluation regiments that help quantify the relative strengths of competing implementations will be essential to the development and refinement of DASM systems and the PBAR devices that operate in them.

- **Repeatability and Uncertainty** – Given the dynamic and multi-variable nature of DASM systems. developing evaluation regiments with acceptable repeatability and measurement uncertainty will present a particular challenge. Nevertheless it is necessary that these evaluation regiments be repeatable within a lab and between different evaluation labs. It is also necessary that the measurement uncertainty be small enough to allow meaningful comparison of results between one system and another. The metrology required by these systems is an interest challenge. What will be required to have assurance that different test systems in different laboratories will give the same evaluation?

Physical Testing

Physical testing of PBAR systems provides its own significant challenges. In this section, several approaches are explored for the physical testing of PBAR devices. Each offers its own strength and benefits.

Conducted Testing

Conducted testing is often selected as the preferred test method because RF environments and measurements may be established more reliably. Similarly it may be assumed that many DASM qualification tests will be best performed by connecting candidate systems, interference sources and test equipment through conducted paths, which can be controlled for relative path loss. Development of conducted system tests will undoubtedly be a significant component of PBAR device qualification. Proper and reliable implementation of such system test beds will need careful development and specification if repeatable tests are to be provided. Test bed qualification regimens will also be needed to assure that different labs perform the same evaluation of a candidate product.

Radiated Test Environments

Most device qualification regiments find it necessary to also provide radiated tests, and it is likely that DASM systems will also require a radiated version of system testing. Establishing stable and repeatable test environments for radiated testing will present particular challenges. In considering the environment to be used in such testing, two RF test methods recommend themselves, gigahertz transverse electromagnetic cells (GTEM) and reverberation chambers.

GTEM Cells

A GTEM puts the test object in a far field environment created by nature of the GTEM cell. GTEMs do not use antennas but the cell itself is the transducer, transforming a conducted signal into a transverse 377 Ohm wave. The test object is then exposed to the same kind of RF environment it would experience in the far field. The input to the cell and monitor instrumentation can be arranged very much like a conducted test, with the required RF environment being created by as many instruments or transmitting objects as are necessary to create the RF test environment. Similarly, using directional couplers the test object’s emissions may be drawn from the cell and monitors for EUT operation under various test conditions.

A particular challenge is how to synchronize the test object function with the test environment. In order to demonstrate compliance with various timing tests, it is necessary to either be able to trigger an attempt to transmit by the test object or to have a warning signal as it prepares to transmit. Such synchronization signals are then used to test the objects ability to defer a transmission within a set time should another transmission occur. It is exceeding difficult to synchronize the test object with the test scenario presentations. The GTEM has the advantage of creating a far field environment with little physical distance from the surrounding laboratory. If the test object software can make available appropriate synchronization signals, then a GTEM based test allows a relatively convenient way of providing these to the test control software.

GTEM cell are likely to fill a significant role in PBAR device testing. GTEM cells are inherently wideband devices, they easily adapt to a wide variety of instrumentation, provide a stable RF environment, and allow convenient access to the object under test.

A wide variety of RF scenarios can be presented to a test object using automated test software. The EUT response would then be recorded and the results compiled. Once test software has been written, automated testing would support testing large numbers of scenarios. This approach makes extensive exercising of a test object under a wide variety of conditions feasible.

Reverberation Chambers

A relatively new tool coming into increasing use is the reverberation chamber. Most test environments attempt to prevent or damp reflections, so as to create a stable, well-controlled RF environment. In exact contrast to these environments, a reverberation chamber utilizes reflections and actually encourages them. In reverberation chambers paddles are inserted into highly reflective cells and moved, mixing the reflected RF signals into a wide variety of combinations. The test object is subjected to a large number of RF presentations by the mixing actions of the stirring mechanism.

Reverberation chambers create extreme multi-path and fading environments. Because they arbitrarily mix the signals inside the cell, it is arguable that they present a test object with a complete sampling of all possible test environments. Because DASM systems require exposure to a wide variety of environments, there would seem to be a natural match between the characteristics of the reverberation chamber and the evaluation needs of DASM systems.

Reverberation chambers do have frequency limits that are size depended. It takes relatively large chambers to support and stir lower frequency environments. GTEM cells by contrast start working at DC and continue to be usable up to the point at which the performance of connectors and absorber components begin to degrade. Generally, GTEMs are considered usable from DC to several GHz, with some manufacturers claiming 18 GHz performance. With a reverberation chamber there is not a natural upper frequency limit. Any frequency that can be radiated can be reverberated. However, the size of the cell creates a lower frequency boundary. Hence, there is a natural difference between the two environments with GTEMs working up to a particular frequency and reverberation chambers working down to a given frequency.

For testing of RF transmitting devices, establishing stable connections in highly reflective environments is a problem and at times not possible. The multi-path inside of reverberation chambers is simply too great to allow sustained link connection. To overcome this challenge, it is likely that modified reverberation chambers would be necessary for DASM testing. Such chambers would introduce enough absorptive material to allow stable connections to be established, while simultaneously retaining significant reflective components with the stirring mechanism, to allow extensive mixing of the RF environment.

In summary there is a significant and exciting challenge to explore the possible methods for presenting a test object with a wide variety of RF scenarios and monitoring the EUT response. Conducting testing, GTEM and reverberation chambers may all come to find a role in full system evaluation. Alternately, it may come about that only a subset of these is necessary to fully evaluate a DASM system and demonstrate its compliance.

Test Scenarios

Qualification testing will require the preparation of a diverse set of test scenarios to present to a DASM system. Happily, this is not totally unplowed ground. (Figure 1)

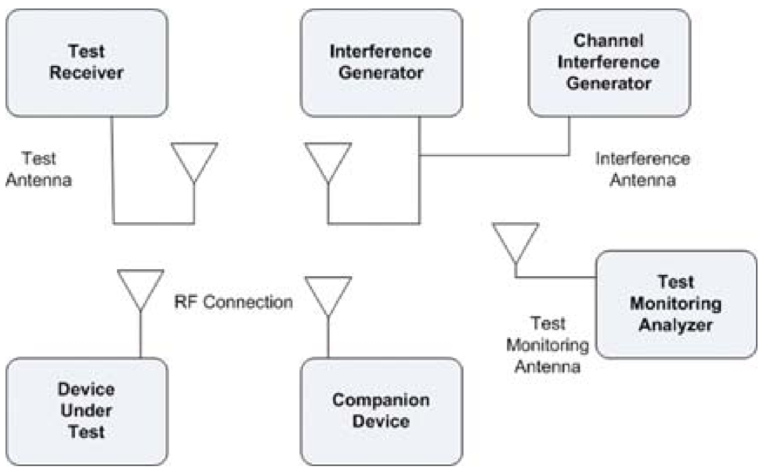
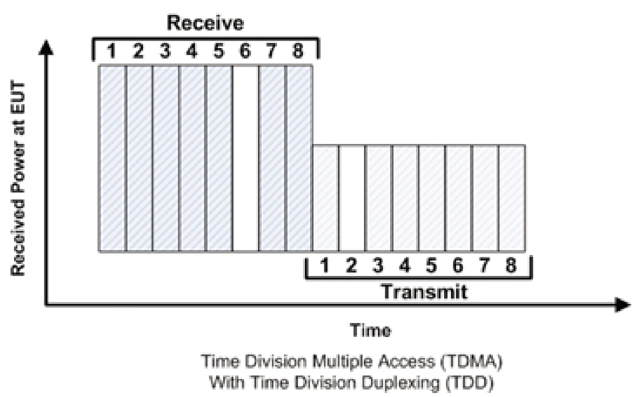


Figure 1: Equipment configuration for a typical dynamic access test

The testing regiments, of necessity, become as complex as the DASM systems being implemented. If the DASM system manages time and frequency as independent variables, then its qualification testing must vary test scenarios with amplitude, time and frequency as independent variables. If a DASM system becomes more sophisticated, managing spectrum using time, frequency, coding and MIMO for signal separation, then test scenarios will be required that independently manage these variables in divergent but controlled combinations.

The complexity of the test requirements should be determined by the candidate system's complexity. Systems designed to support duplex connections, delivering real time services will require stressing those connections. The illustration in Figure 2 from ANSI C63.17-2006 shows how interference with controlled amplitudes, relative time and frequency will be required to test the appropriate response of the candidate system.



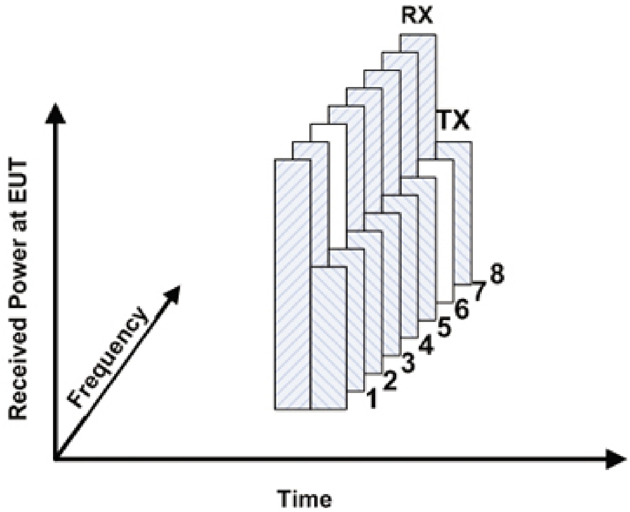


Figure 2: Testing of TDMA and FDMA duplex systems requires simultaneous and coordinated control of frequency, time and amplitude

Similarly complex will be the test monitoring system, which must become RF analogs to logic analyzers, monitoring a number of events simultaneously so that their relative timing and amplitude and other variables may be studied.

Qualification Paradigms

A very significant companion task for qualification testing is clearly defining the purpose of the qualification testing. Is this testing being performed to demonstrate proper system function, non-interference or only efficient use of spectrum? These issues become extremely important when qualifying a product. To have clear and objective qualification regiments, consensus solutions must be developed and promulgated. Simply put, the regulator has one set of concerns and the system operator has a different but sometimes overlapping set of concerns.

For cell phones such a division has been developed in which a mobile handset must first receive an FCC equipment grant, and then receive CTIA approval, before most carriers will accept the device into their network. The FCC equipment grant is limited to issues of spectrum use while the CTIA certification is focused on operational performance in a cellular network.

The advantage of this dual system is that it allows the regulatory requirements to be managed exclusively by the FCC, knowing that other important issues will be managed by the CTIA certification. Such a division of responsibility supports a consistency of scope, which may not be possible otherwise.

There are a number of issues, some of which can be identified now. Others will certainly arise as specific DASM implementations are proposed, and as these implementations become increasingly complex, using more variables to increase spectral efficiency and achieve other benefits. Therefore, it is to be expected that specifications and test cases will arise from both engineering analysis and field experience.

It is important to identify these issues as soon as possible. For each issue, its potential impact to spectrum efficiency or system operation must be explored and understood. Then, a consensus must be developed to assign this to an appropriate sphere of qualification. Some issues will appropriately be assigned as a spectrum management concern. Implementations that fall outside of certain parameters should not be allowed to operate. Other issues will not degrade spectrum efficiency or create increased interference directly but may affect system performance. While important, these issues may be assigned as system qualification issues. The authority responsible for approving system components may be willing to accept degraded performance because of other benefits being delivered by a particular implementation.

However, seldom will issues fall completely into one area or another. An issue that degrades system throughput may result in increased system traffic as more retransmissions are required to successfully deliver the required data. The retransmissions will utilize more spectrum, degrading spectrum efficiency. So, as a secondary effect, system efficiency will affect spectrum efficiency. Such arguments can become increasingly complex, going to 3rd and 4th order effects. Qualification paradigms, representing consensus agreements, are required to support system qualification and avoid delays due to different qualification philosophies.

Clear boundaries and qualification parameters will be essential to the advancements of DASM systems. Without such definition and support, DASM systems will be hindered due to conflict over these issues and a perception that the systems are not sufficiently matured to be trusted in full deployment.[6]

Probability of Detection

Particularly difficult qualification issues arise when system performance depends on multiple variables. An example arises when considering a system with blind slots being tested for proper channel selection in a least interference channel system. The issue is whether a system qualifies if its probability of detecting a spectrum opportunity falls below 100%? If so, at what probability of detection does it fail to meet requirements? In this example, the technique being tested requires that a device monitor a large number of channels and select the channel that has the least interference, below a certain threshold.

To test least interfered channel requires that all available channels have interference introduced on them at defined levels. One channel is left interference free. To pass the test, a device must show that it will properly select the open channel.

A complexity arises when evaluating compliance with a system with blind slots. Using the system described above with blind slots created by it reaction time, the ability of the system to identify an interference free channel will be limited by these blind slots. Figure 3 assumes a system in which a dummy bearer is used to synchronize operation. It shows that, for some relative assignment of a timeslot for the dummy bearer and the available channel, the system will pass, but for other relative assignments it will fail. The question then becomes whether or not the system passes or fails the qualification test?

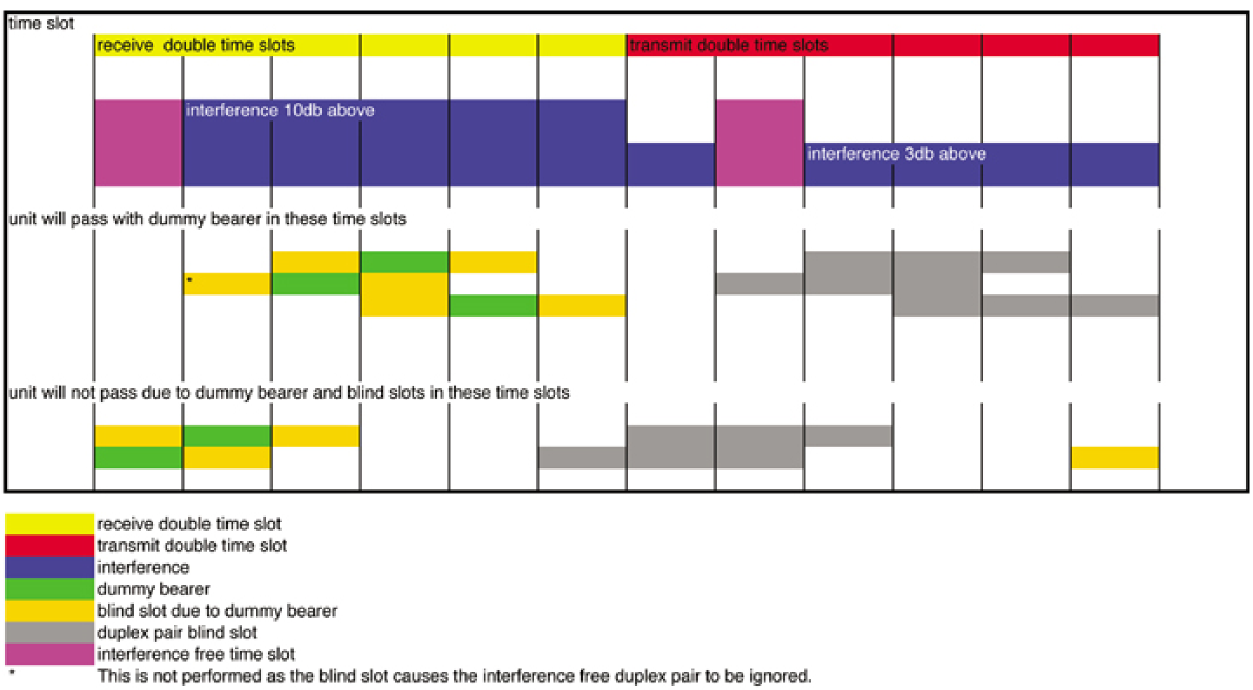


Figure 3: Blind slots create non-detectable transmission opportunities

In the illustration, the system will properly identify the available, non-interfered channel in 3 of 6 timeslots, but fail to identify it in the other 3 timeslots.

Perhaps the core question is, "What probability of detection is required for a system to be judged to have successfully implemented a technique?"

Test System Capabilities

The ability to test is built upon the capabilities of available test systems. In the illustration below interference is introduced to test channel access in a fixed frame system. As can be clearly seen, the interference generator has a defined bandwidth. A threshold is defined, but the interference, while it will cross that threshold at a given point (defined to be at the channel edge in this illustration), has only slightly different energy levels on either side of the boundary. This physical requirement of real test systems and test uncertainty created by the precision with this the system can control the amplitude or frequency of the interference creates a limit on the ability to test the candidate system.

While the issue illustrated is reasonably straightforward, other test system dependencies are not. It is not uncommon in complex tests to have divergent results that, when analyzed in detail, reflects not differences between candidate systems but differences in test system capability.

End Result Correlation

Ultimately, a qualification regiment is an abstraction that is intended to predict a desired real-world result. Because the qualification regiment is an abstraction, its efficacy in predicting the desired result is always questionable and mostly like imperfect. The degree to which a qualification regiment correlates to the desired result is typically a subject of ongoing debate. Finding an acceptable level of correlation for PBAR and DASM systems will be a consensus building process in the end. A balance is necessary between the compliance cost and the degree of confidence delivered that specifications are met.

It is not unusual, especially with new technologies, to observe many suggestions for 'improvements' to the qualification regiment being offered. In some cases, when good review and adoption processes are not in place, effective adoption of refinements and new innovations to a qualification regiment is missed. Alternately, too many tests may be adopted and the CAS system becomes a significant barrier to innovation and promulgation of a promising technology. An effective CAS system would have processes that would see the adoption of innovations that deliver solid benefits at reasonable cost and would reject those that fall short but simultaneously protect it from inordinate growth and complexity.

With a system as complex as a DASM system, the qualification regiment could easily become quite expansive. The CAS systems must be efficient for DASM systems to advance.

Much will be gained if the first qualification regiments have solid justification in correlation to the desired end result. Further, if the rational and process of adoption or rejection of candidate elements of the regiment are clear, a process will be established by which to judge and select among future candidate tests. Effectively correlating the qualification regiment to real-world performance will require the difficult but very important task of having good real-world performance information to compare with the results of the qualification regiment or to candidate elements for that system.

Test Repeatability and Uncertainty

For complex measurements and evaluations, the issues of repeatability and uncertainty are significant. Certainly for an evaluation as complex as those required of a DASM system, there are significant challenges to achieving repeatability and uncertainty within acceptable bounds.

Given a complex test, there is a significant chance that two different laboratories will arrive at different results when evaluating the same system. Even the same lab may arrive at different results when evaluating the same system at different times. However, test repeatability and uncertainty must be dealt with when designing a CAS for DASM systems.

Metrology

Metrology is likely to take on new meaning in this arena. As these systems bring together radio design, computer science and software control in new ways, the metrology supporting the conformity assessment testing must follow and support these new configurations.

Perhaps one example will suffice to make the point. Let us assume that some tests of timing and response requirements will be implemented by using vector signal analyzers to record spectrum regions while an EUT is required to respond in a defined manner to changing spectrum presentations. The vector signal analyzer will be acquiring and storing to disk the test sequence and the EUTs response to it. The ability of the instrument to capture and store a continuous stream of information without interruption will be critical to the accuracy of the measurement. Calibration of a signal analyzer's ability to buffer and store data without interruption is not a traditional part of calibration but it may be in the future.

In this scenario, the determination of compliance is not made directly but rather will be determined from the stored data. Therefore, the fidelity of the data will very possibly be a significant factor in the measurement uncertainty. The closer an instrument can reproduce the events, the closer to the margin a measurement may be made with accuracy.

Hence, as measurement, of necessity, follows these new classes of devices from the physical domain to the logic domain, the calibration of the test instrumentation and test systems must follow across those boundaries.

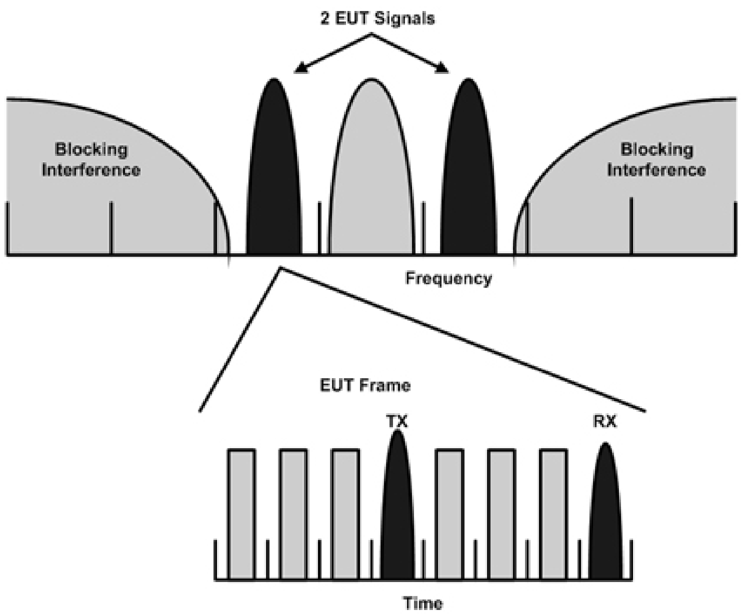


Figure 4: Testing channel access in a TDMA fixed frame system

Conclusions

This article has presented the elements of a generic CAS system and explored the particular challenges presented in designing a CAS for PBAR operating in DASM systems. These qualifications may be a designed mixture of software and hardware evaluation through direct testing with simulations and analysis. New methods for performing conducted and radiated tests will be required. Having clear and technically mature test standards is essential if these requirements are to be met. It is this challenge that the IEEE 1900 series of standards seeks to meet.

Until satisfactory qualification regiments are available, regulatory adoption of DASM systems may not be possible. ■

Notes

1. In the current draft of IEEE P1900.1 "Policy-Based Adaptive Radio" is defined as:

> *"A radio that is governed by a predetermined sets of rules for behavior that are independent of the radio*

implementation regardless of whether the implementation is in hardware or software and both senses and adapts to its environment. The rules define the operating limits of such a radio. The definition and implementation of these rules can be:

- *during manufacture or reconfiguration;*
- *during configuration of a device by the user or service provider;*
- *during over-the-air provisioning; and/or*
- *by over-the-air or other real-time control."*

2. ISO/IEC 17011:2004 replaced three sets of overlapping requirements for the same attributes: ISO/IEC Guide 58:1993 (laboratories), ISO/IEC Guide 61:1996 (certification bodies) and ISO/IEC TR 17010:1998 (inspection bodies).

3. Conformity assessment systems check that products, materials, services, systems or people measure up to the specifications laid out in a relevant standard. A lack of confidence in their competence to perform these tasks may result in redundant, costly and time-consuming assessments by different accreditation bodies in different countries. Such costs could be drastically reduced if a conformity assessment body, supervising such a system, can be assessed once and the results accepted globally.

4. ISO 17011 aims to harmonize requirements worldwide for organizations that assess the competence of "conformity assessment" bodies. It will provide a global benchmark for "accreditations bodies" to ensure that they operate in a consistent, comparable and reliable manner. It sets out a uniform set of requirements for bodies that verify the activities of conformity assessment bodies - from testing, inspection, management system certification to personnel certification, product certification and calibration.

5. Typically between 3-10 devices must be tested to provide this level of confidence. This number of tests on a large production volume is not usually considered overly burdensome.

6. These considerations may recommend that, with in the IEEE 1900 series, a test standard be developed for spectral efficiency (perhaps 1900.4?), and that a different evaluation be developed for system operational efficiency (perhaps 1900.5?).

7. The current version of ISO 9001 replaced the previous version of ISO 9001 as well as ISO 9002 and ISO 9003.

References

- ANSI C63.17-1998, *American National Standard for Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices*
- ISO 9001:2000 Ed. 3 *Quality management systems — Requirements*[7]
- ISO 9004:2000 *Quality management systems — Guidelines for performance improvements*
- ISO 10007:2003 *Quality management systems — Guidelines for configuration management*
- ISO 10012:2003 *Measurement management systems — Requirements for measurement processes and measuring equipment*
- ISO/TR 10013:2001 *Guidelines for quality management system documentation*
- ISO 10015:1999 *Quality management — Guidelines for training*
- ISO/TR 10017:2003 *Guidance on statistical techniques for ISO 9001:2000*

- ISO/IEC 17011:2004 Ed. 1 *Conformity assessment — General requirements for accreditation bodies accrediting conformity assessment bodies*
- ISO/IEC 17024:2003 Ed. 1 *Conformity assessment — General requirements for bodies operating certification of persons*
- ISO/IEC 17025:2005 Ed. 2 *General requirements for the competence of testing and calibration laboratories*
- ISO/IEC 90003:2004 Ed. 1 *Software engineering — Guidelines for the application of ISO 9001:2000 to computer software*

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