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A Telcordia Technologies Company

Specifying Spectrum Management Systems

Avoiding Pitfalls at System Acceptance

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Synopsis

Spectrum resources need to be managed in order to make an optimal contribution to the national economy. The detailed approach taken to spectrum management tends to vary in line with prevailing economic and political forces: countries tending towards a command economy usually favour direct control by a regulator, whereas those with mixed economies tend to favour philosophies that let markets decide who gets access to what spectrum.

Regardless of their political colour, however, all economies tend to rely on information and communications technology systems in order to implement an effective spectrum management regime. Whilst underlying economic policy may affect the approach taken to spectrum management issues, neither has much bearing on the method of specification of the electric system used to effect day-to-day management. Failure to adequately understand, control or drive the development and implementation of a spectrum management system, however, can have serious ramifications for regulators, users and the economy in general.

This paper discusses how ICT-based spectrum management systems should be specified - whether by development or procurement processes - in order to lead to a high-quality outcome. It is appropriate for all spectrum managers, regardless of what sort of economic system they inhabit.

The electromagnetic spectrum needs to be managed in order to contribute adequately and appropriately to the gross domestic product of a nation-state. That fact is without dispute in governments worldwide. The approach to spectrum management varies with the colour of the economy: those tending towards command economy favour command and control by a regulator. Those in mixed economies favour philosophies that let markets decide who gets access to what spectrum. In all economies, information and communications technology systems are commonly used to effect spectrum management. The approach to spectrum management has little bearing on the method of specification of the electric system used to effect day-to-day management. This paper concerns such electric systems and is appropriate for all spectrum managers, regardless of what sort of economic system they inhabit.

Specification of spectrum management systems is essential. One assumes that such a system is to be developed or procured and both are risky without expression of the user need and translation of this into something that others can understand and realise. From a contractual view too, lack of specification suggests an open liability – something that today is unacceptable to most managers.

Before we begin the discussion on how to go about this specification development it is critical that we scope the system. We must remember that the spectrum management system includes human operators, computer processing, data storage and spectrum sensing devices. We need quickly to determine the system boundary. This is a management issue and probably the simplest way to express this is through a system diagram:

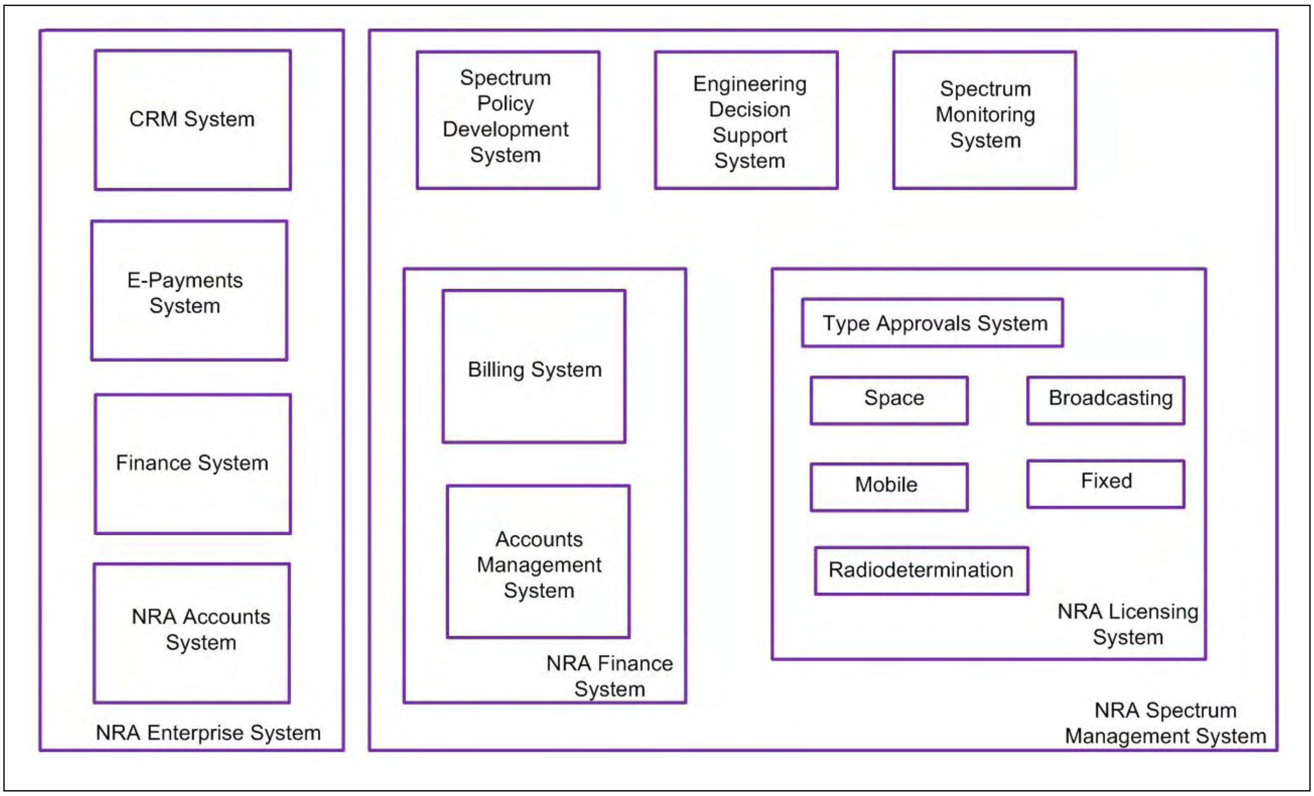

Figure 1 - The System Boundary

For the purposes of this example, the system boundary excludes spectrum monitoring: the sensing devices. It includes the raising of bills for payment but excludes the payment systems that cause these bills to actually be paid. It includes an element of spectrum access request to be made via the Internet. It says nothing about the detail of these systems save that they exist and are distinct one from another. Furthermore, it says nothing about how the system will perform these functions, what technology will be used or the degree to which technology will aid the user. At this stage it could be a manual system using an abacus for computation and papyrus for storage.

There are many momentous failures in computer systems. The primary error that project managers make in their implementation is to expect computer systems to solve problems that have not be fabricated in human and paper form first. If there are no processes and procedures, no data to be processed and no information to be stored, it is unlikely that a computer solution can be successfully applied to solve a problem that has yet to manifest itself. The first message, therefore, is to understand the system boundary and perfect the existing system within the boundary, not attempt to solve some other problem that will only appear when the computer system is in place.

The Problem

So we've established that the computer solution (for that is surely in this modern age what it will be) exists to solve a real problem. That said, what is the deal with the specification and why is there anything to say about it? Is it not a case of just writing it?

A specification is a communication. As such it has a reader: someone who will take the specification and do something with it. With that in mind it is critically important that the author understands who he or she is writing it for and what effect it is to have in the reader's mind. The reader is expected to do something with it and this must be acknowledged from the outset. This has bearing on the document's language. If it is to be read by lawyers and economists as well as engineers, it must speak to them also. If the reader will be reading in his or her second language, it may be that diagrams may prove more expressive than text alone. As a specification is a document that conveys information, it must do this unambiguously. Ambiguity means problems at system handover when user expectations differ from the system features. The specification is therefore a key instrument to manage risk and it does this by controlling feature and function to perfectly meet the requirements of the organisation acquiring the system. It has a life that starts when the system is just fleeting ideas and ends at acceptance testing and user training. It is not just important. It is the key document.

Outline Production Process

A specification is a capture of requirements. The operative word here is capture and this means that the engineer responsible for the capture must elicit information from those who develop and use existing systems within the regulator. Some examples are useful. In many regulators, systems are still paper-based; an example is a page per channel to describe PMR assignments. In others, the proprietary Excel spreadsheet application is used in an isolated fashion with one Excel line for every fixed link. What is necessary is to capture the process of licensing as well as the data capture and processed.

Methods of capture vary. Interviews are the most useful but tools are needed to aid this. The most common tool is a system model and this will be discussed in full later in this paper. Other possibilities include taking snapshots of data at each stage in order to describe states and hence state transitions which can be described by diagrams – state transition diagrams. Structured interviews are also popular though, in order to form the structure, some knowledge of what is needed to be captured is essential.

There is already a structure available from the ITU and anyone contemplating specification of a spectrum management system should first read the texts from the ITU-R covering spectrum management for developing countries (SMS4DC), even if their country is not what might be considered 'developing'. The basic structures there provide a start point for all system definitions. Similarly, international and regional standards will form an important core, particularly for technical analysis.

There have in the past been many such specifications written, many simply from the SMS4DC or directly from SM 1370. These existing specifications are, on the one hand, dangerous documents, for it is all too tempting to copy requirements from them, simply assuming that all spectrum regulators do their business the same way. On the other hand, they can be a rich source of text and of 'boilerplate' requirement; stuff that is always there because it is built-in to the ITU framework to which member states are committed. Such specifications are also useful as benchmarks, perhaps for evaluating existing systems. Ultimately, they must be used as a resource, but used with care.

A specification is a huge document that is a communication to a designer who will enter a contract for system supply. As a communication, it must talk to that designer. Typically system designers are software engineers. There may also be a spectrum management domain expert on the design team though often the domain expert is spread across several projects. Your specification must therefore talk computer system language, perhaps using UML or other diagramming languages as well as text. The specification must be adequate to unambiguously define the system such that the supplier can get the design right first time leading to satisfied users. Ambiguity is often only found at the acceptance testing in the final stages of the project and, at that stage, the result is usually disastrous. Finally, within the scope of the system (defined by the system boundary), the specification must be complete.

There are three aspects of specification: functional, non-functional and constraint. The functional aspects are those which the user applies to achieve some task for which he is responsible. The non-functional aspects are those which must be met but that are not linked to task. An example is the operating system under which applications must run. Constraints are just that and might include available processing power, data storage or the likes.

That brings us finally to the most important aspect of a specification: the statement of purpose. Very simply, if those who specify get the wrong purpose, they are likely to define the wrong system. Purpose is what business benefits the managers of the regulator intend the system to deliver in return for the investment they will make. Most purpose statements are a few sentences and might be of the form:

> "The Commander in Chief requires to assign spectrum to his operational, joint, inter-agency and multi-national combat units such that they enjoy a spectrum quality commensurate with their operational needs in Worldwide theatres from now until 2025".

This meets the need to express that the capability "does something to something to achieve a result". Note the use of the term 'capability': it is an amalgam of computer system and human operator that forms a capability, not simply a computer application.

Tools

So you'll interview regulator staff – how? It's a simple statement to make and a hugely difficult thing to actually do. It's common to cite this at the point of bidding for work and it sounds good, like you will involve folk who are currently doing the work. It must however have structure for it to work. The most useful tool at this point is the diagram. The only constraint is that it must be one of the family of recognised diagrams with an inherent structure and form such that everyone who might read it will understand; and if they don't they can find further details on that type with which to update their knowledge.

The interview might therefore proceed like this:

> "So what's the trigger (diagram input) for all this activity?"

"And what's the resulting documentation (diagram output)?"

"And how do you work to convert the input to the output (process)?"

The result is a structure to the interviews that actually builds the specification before the interviewee's eyes.

And so you'll read documents – how? The same basic question arises. In the tender response to win the work you will read that which the tenderers will read. The problem is that without tools, the information goes from document to reader's brain. What happens thereafter is unclear and depends on the abilities and bias of the reader. It is better to capture information to an intermediate tool such as Mind Manager, from where the captured data can be organised and sorted into an appropriate argument to express the requirements point.

Not all spectrum regulators are the same. Some have interest in type approvals, some don't. Some are constrained in available spectrum (and invoke engineering analysis) and some have plenty (and don't have an engineering group). The specification between regulators will therefore have similarities (with the ITU treaties as core) but big differences also. One of the first tasks is to identify the players. The most effective way to capture this at a high level is by way of a rich picture. This is a stylised organisational diagram that might show the actual people, their functions or just departments. UML Use Cases are another effective way, particularly because they demand identification of who 'uses' what parts of the spectrum management system as shown below:

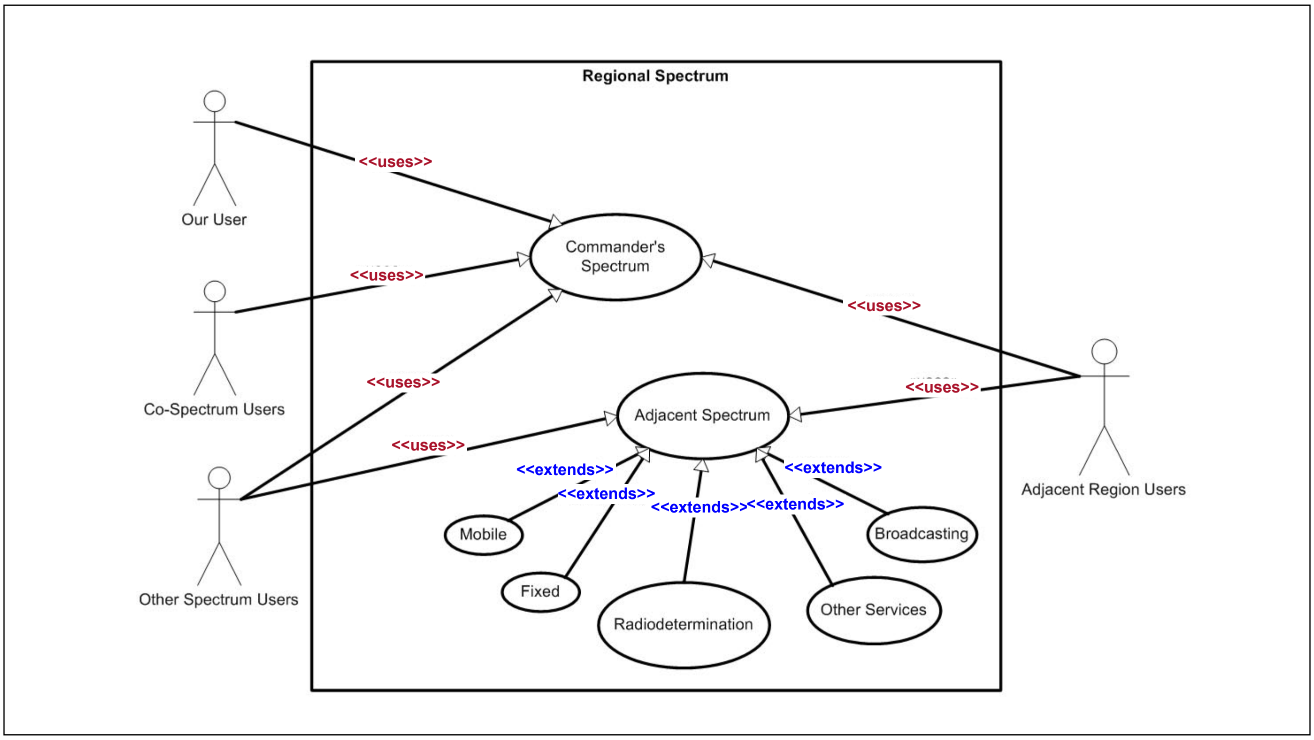

Figure 2 - Use Case Model for a Defence Spectrum Management System

Diagramming is the specifier's most powerful tool. It permits the specifier to express the structures and processes as a series of views. Note, however, that they are just that - views. A flow chart, for example, does not tell the whole story. It will need other views to complete the description.

Commonly there are two disciplines which contribute to a spectrum management system: the software engineer and the radiocommunications engineer. The single biggest failing of many is to only make use of one discipline. Software engineers are good at eliciting requirements: general requirements. This often works well if the customer knows exactly what he wants and there have been many systems designed from the bottom up in this way. They are usually one-offs, not reused and with a short life. The second discipline is radiocommunications. Often this discipline alone is used by customers at the specification phase. In this case the bias is to technical detail in propagation, interference and other low level detail. To adequately specify a spectrum management system, both disciplines are needed in equal measure.

Further tools include workshops with all stakeholders, questionnaires and consultations. A spectrum management system touches many people's working lives and hence many have opinion beyond the immediate users and specialists.

Specification Development Process

One has to be explicit about what a specification is. There are three common specification types: the user requirement, the functional and the system definition. The user requirement specification (URS) is the first in the hierarchy. It is just that: it says what the user requires to be able to do when using the system. It therefore talks in user language. An example might be "the user requires to be able to assign a channel to a station". It says nothing about how this is to be done. It could be done with an abacus and papyrus or it can be done with a multi-million dollar computer system. Which it uses will be arrived at and specified later when the specifiers define the time to be taken, the overhead cost per assignment and other metrics that show that really the only solution will be a modern computer system. This type of language is perfectly unambiguous. At the acceptance stage one simply has to ask "can he/she?" and, if the answer is "yes", then the system is compliant. It will take between 100 and 200 man days to develop an effective user requirement specification for a spectrum management system.

The functional specification (FS) takes the URS and says how this is to be done. It may take the requirement noted above and say that "the system shall aid the user in making a channel assignment by suggesting a seed channel. That seed channel will then be appraised for interference at that location and equipment specification."

It still does not actually dictate how exactly this is to be done but it mirrors the users' policies in making assignments – to appraise a seed for interference and then perhaps suggest a new candidate channel if the interference is too high. It is important that the FS is seen as completely separate from the URS. It is also important to note that when it comes to acceptance, it is against the URS and not against the FS. The FS may be used in lower level testing activity but the measure ultimately for acceptance is "can he?"

Finally, the lowest of all specifications is the system design specification (SDS - sometimes called the detailed design specification or detailed design document). This is the specification that says in system design language how the system will generate the seed channel, perhaps scanning all channels in the band, calculating the spectrum quality or noise floor in each and then selecting the first one that offers at least a given threshold. The system design specification is at the algorithm level and from this the software engineer can develop his code. Often pseudo-code is used for the SDS. The SDS is used in module testing in the software development activity. The FS is used to develop the system testing that will be done by the supplier on the whole system prior to acceptance testing with the customer. As noted above, the URS is used for acceptance testing. This shows a nested set of specifications that lead from one to the other and this is shown in the diagram below:

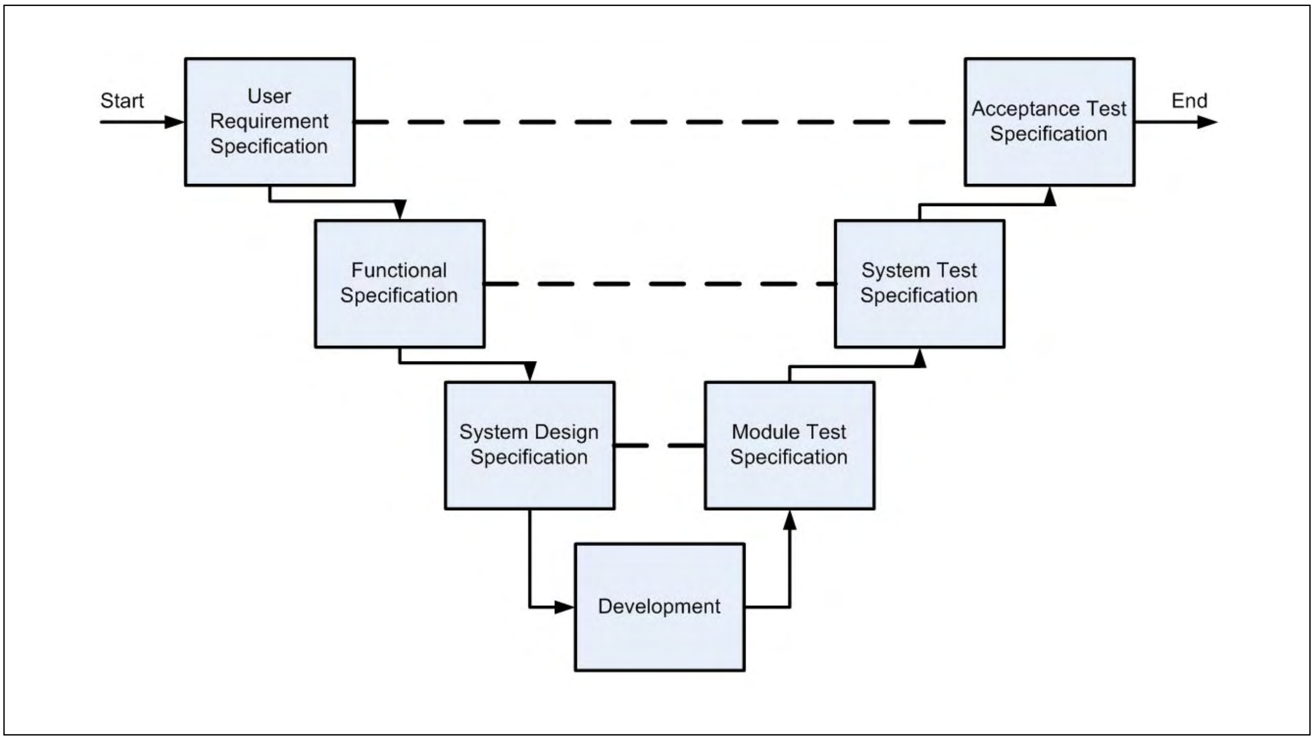

Figure 3 - Waterfall Model with Relationship of Specifications

All of this presumes that an adequate purpose statement has been made and agreed, otherwise all the specifications are built on sand.

We should, of course, note that this assumes that it is possible to elicit the requirements and add more and more detail to eventually culminate in the SDS. It is critical that those asking for such specifications understand and acknowledge that it may often be impossible to develop an adequate specification. It may be that there are no policies in an area. Perhaps the regulator has no satellite filings but will undoubtedly move to make filings in the coming years. This might mean that no-one knows how this is to be done. In this case there are other lifecycle models from the software development domain that can help. The iterative model is possibly the most useful. It calls for an outline specification, a development of something that moves the user forward, but everyone acknowledges that this is not the final solution and over a period the features of the system will evolve.

So where does the material come from to build the specification? The first source is primary data: interviews and workshops with the users. Then next is secondary data such as telecommunications and competition laws and decrees and organisation policies, plans and existing ways of doing things. All material, whether primary or secondary, must be assembles and scanned for function points for functional aspects and for non-functional requirements and constraints. Function point definition is the subject of a vast current knowledge base and other publications give good treatment for those wishing a more detailed description. What is important here is that the specification development team invent nothing. All points in the specification must come from primary and secondary data. All must have their source in other documents and be extracted. This then means that there is complete traceability from the user, through the URS, FS and SDS to the eventual system produced.

The Link to Purchasing and ITU Recommendations

The above hierarchy of specifications makes the assumption that the system is to be developed from policies and procedures and from user requirements. In spectrum management there are many inputs to the requirements from the ITU. This is helpful on the one hand but, on the other, it creates a huge smokescreen. By specifying, the ITU has made the assumption that all regulators will do the job of spectrum regulation in exactly the same way. It is also useful to note that the ITU's thinking and documentation is about ten years behind progressive thinking on many subjects. An example is the current popular thought on neutrality which is not yet enshrined in ITU methods.

The hierarchy also gives a structure to the whole purchasing activity. If - indeed - the regulator does want to run many of his activities exactly as the ITU suggest, then the specifier simply references the relevant ITU document. What, however, is critical is that there is a URS and that this document is written on behalf of the user. It is this document that can be sent out to would-be suppliers as part of a purchasing activity. If there are specific things which the system must do that cannot be achieved by simply referencing other documents, then an FS will need to be prepared. Even where the supplier has an off-the-shelf solution, there will be modifications that should be controlled and tested for using the SDS – even if the supplier writes it. The above gives a framework. It says what is to be done and it permits test to confirm that what was to be done has indeed been done. It can be moulded to local needs but ultimately - if followed - it will lead to a high-quality outcome.

Conclusions

The development of specifications for spectrum management systems requires two disciplines – radiocommunications engineering giving domain knowledge and software engineering giving the discipline of software engineering. Both are needed in equal measure. Specifications are engineered. The lifecycle of the specification writing project follows a form that is well developed in InterConnect. It makes use of best practice from both radiocommunications and software engineering domains.

There are many competencies needed in the specification team. To conduct interviews needs interpersonal skills, particularly where the interviewer is working cross-culture. To elicit function points from a plethora of regulator documents takes knowledge of typical regulator business spanning the disciplines of radiocommunications engineering, economics, law and politics. These competencies are not often found together in consulting firms in adequate measure. InterConnect has completed such specifications for a host of regulators and other spectrum management organisations. Call us for a discussion on the subject to see how we might help you.

The Author

John Berry is InterConnect Communications' Director of Spectrum Services and a radio communications expert with 30 years' experience in the mobile, fixed and broadcast radiocommunications industries, military radiocommunications and in radio spectrum management. The holder of a BSc in Electrical and Electronic Engineering, a BA in European studies and an MBA majoring in technology management, John is a Chartered Engineer and a Fellow of both the Institution of Engineering and Technology and of the Chartered Management Institute. John's role within InterConnect is to lead the development of the spectrum services product line. In this he manages major spectrum management projects and is an active consultant across the spectrum management domain and in wireless network design and implementation.

Prior to joining InterConnect, John spent some 13 years as Managing Director of ATDI Ltd, leading a series of major radio and spectrum management consultancy and software engineering projects which contributed hugely to Europe's telecommunications infrastructure and spectrum management policies. Prior to that, he acted as Business Unit Manager for MEL Communications (part of Thales Communications), establishing a civil products group within this military systems integrator majoring on spectrum monitoring, spectrum management and communications planning. John has also served in product development and marketing management roles for Maxon and Philips, covering product design, systems engineering and network planning.

John has presented some 60 technical papers and 20 technical/management workshops across Europe on spectrum-related topics, and is a patent holder in radio measurement techniques.

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InterConnect Communications

InterConnect Communications is a wholly-owned subsidiary of Telcordia Technologies Inc., based in the United Kingdom, and a leading provider of consultancy services on spectrum and wireless technology issues.

InterConnect has over 20 years experience in managing the radio spectrum at international, national and local levels, and has evaluated, specified, procured and implemented spectrum management and monitoring systems for all size of regulator and administration in countries across the globe. InterConnect has not just worked with numerous organisations to implement such systems but is recognised in its own right as one of the world's leading independent experts, with knowledge of the capabilities of all manufacturers in the field. We have supported the procurement of a wide range of spectrum management (and monitoring) systems using national and World Bank procurement rules.

For more details of InterConnect's radio spectrum services, please visit http://www.icc-uk.com/spectrum.php or e-mail us at spectrum@icc-uk.com

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