White Paper

RF & Microwave Test:
What is the Optimum Strategy?

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For the OEMs of RF and microwave products, verification through test is a crucial part of their quality assurance. However, the design and construction of automated test equipment (ATE) is a considerable drain on engineering resources, taking engineers away from their core product development duties.

It is the responsibility of the business owners, directors, and other stakeholders to employ a strategy that minimizes that drain on resources while ensuring the ATE produced is fit-for-purpose and that tests are highly repeatable. Also, in the event of an increase in production, it may be necessary to produce an identical ATE later. Again, this must have minimal impact on day-to-day product development tasks.

In this white paper, we consider the three ways in which an RF/microwave ATE might be designed and built , specifically focusing on the signal switching and distribution subsystem.

RF & Microwave Objectives and Challenges

Products that employ radio frequency (RF) or microwave signals (MW) for the transmission of data (sometimes at high power) need to be tested as part of their quality assurance. Moreover, for some products their performance characteristics must be recorded at the final production stage for inclusion in datasheets, certificates and other paperwork that accompanies them when shipped.

In a production scenario where manual verification methods can be time consuming and error-prone, the use of ATE makes sense. The test equipment will typically include expensive RF/microwave stimulus and measurement instrumentation such as spectrum analyzers and signal generators at a minimum. It may also include more specialized equipment, such as a vector network analyzer (VNA) or, in rare circumstances, instrumentation for confirming phase matching and controlled signal lengths. There will also be a control system (typically PC-based) and a variety of switchgear. In many cases, the instrumentation I/O needs to be shared or distributed across many test points on the device being tested. To manage size, complexity, and cost of the ATE system in these instances, a signal switching and distribution system is often considered.

Depending on the complexity of the tests, the engineering team has one of three options for building their ATE: Once a decision is made to utilize a signal switching/distribution system in the ATE, the engineering team has a few options to consider for the base architecture of this system:

- Use an industry standard/COTS modular chassis/rack system and additional (external) interconnect cabling to construct the subsystem.
- Use a COTS chassis/box product and additional (external) interconnect cabling to construct the subsystem.
- A turnkey solution that includes (internal) interconnect cabling between the RF/microwave components.

Before discussing each in detail it is worth stressing that any ATE platform is a means to an end. It is the platform's ***capabilities*** that are of paramount importance. They govern how thoroughly and how quickly the design under test (DUT) can be tested, which in turn supports the OEM's business growth and reputation for delivering quality products.

Importantly, test accuracy must not degrade over time, even after many millions of operations. And if there is ever a need for a second ATE – to support an increase in production, for example - for any given DUT, the test results must be the same irrespective of which ATE is used.

So, let's look at the three ATE build options.

Build Option 1 – COTS Industry Standard Modular-based Subsystem

If the DUT is not too complex, and the engineering team is already familiar with industry-standard chassis and backplane systems, this option provides great flexibility. For example, PCI eXtensions for Instruments (PXI) is a popular PC-based form factor for measurement and automation systems. NOTE: PXI also encompasses PXI Express for the purpose of this discussion.

A PXI chassis provides power to and cooling for PXI modules (figure 1 shows some examples) as well as a communication bus. Communication between the host PC and the PXI modules is either through a PCI bus extension module or through a host controller that is embedded in the PXI chassis. In this respect, PXI is very plug-and-play, and it could be that if the engineering team already has a PXI-based RF measurement system, implementing the tests could be as simple as adding a few switching modules and a software driver. The PXI form factor also delivers flexibility to custom-configure a COTS switching solution that consists of different switch topologies (SPDT, SP4T etc), frequency ranges (DC – 110 GHz) and self-termination options.

Figure 1 – Above, a range of PXI modules and a PXI chassis.

In cases where it is not desirable to use PCI/PXI extension kits or a PXI embedded PC, another popular standard for communicating with PXI form factor modules is the LAN eXtensions for Instrumentation (LXI). LXI defines the communication protocols for test instrumentation via Ethernet and allows for a simple connection scheme. All that is needed to connect to an LXI device is a CAT5e cable. LXI card-modular chassis embed a PXI backplane and can therefore accept PXI modules. While the LXI-enabled chassis looks like a PXI chassis, the one important caveat here is that LXI modular chassis only accept modules made by the chassis manufacturer.

Figure 2 – Above, a selection of LXI modular chassis with PXI modules.

These card-modular solutions offer some advantages for system engineers. As a modular form factor, maintenance logistics can be simplified. Individual modules can be spared and in the event of a relay failure, a simple swap of modules can get a system back up and running quickly. Additionally, each module can be considered a building block that is part of a larger switching network. If multiple products are to be tested with a single ATE, the building blocks can be reconfigured with external cabling and adapters as needed, providing a very flexible platform. For example, a system comprised of 8 SP4Ts can be wired externally as a 4 x 4 matrix for one test, or two SP12Ts for a second test.

This flexibility can often come at a performance cost that is unacceptable. Connecting components with external cabling may add length and loss to a signal path. External cables are also more prone to damage by technicians working on the system. Also, it can be particularly difficult to keep consistency in cable forming/routing across system builds which could affect consistency in test results. How much of this tradeoff in performance can be accepted will determine whether a modular approach is appropriate for a system design.

Build Option 2 – Flexible LXI Products

A key decision in whether a card-based modular switching subsystem is appropriate for a test system is often physical. Regarding Figure 1, the rightmost PXI module is a two-pole, six-throw RF switching module. Though the functionality is provided by a single PCB, the front panel occupies the space of six slots. It may be desirable in a system design to reserve as many PXI chassis slots for instrumentation that benefits from the speed of the PXI backplane. Other considerations include payload (some test equipment is not available in PXI form factor), and acceptable interfaces (including remote access). Indeed, while a card-based system is extremely flexible it can soon become a space-hog if even a moderate level of signal switching is required.

In contrast to an industry standard card-based architecture, the LXI standard does not define any specific mechanical dimensions and a switching/routing subsystem can take virtually any form factor. In application scenarios where the flexibility of a building-block approach is desirable, an LXI-boxed-based solution can provide a space and cost-efficient option. Figure 3 shows a selection of Pickering Interface's LXI box-based products. Significantly more switch payload can be accommodated in significantly less space when compared to a card-based solution.

Figure 3 – Above, the LXI form factor can accommodate more payloads and makes better use of space. For instance, the second box from the bottom provides 12 SP6T and 12 SPDT RF relays.

Fundamentally, the card-based and box-based solutions provide very similar functionality as it relates to the system design. Both can be 'custom-configured' with relay types that meet the exact needs of an application. The Application Programming Interface (API) provided for each is very similar. In either case, a variety of connectors and cables will be required to benefit from the flexibility the form factors provide. However, as previously mentioned, this could potentially result in unacceptable performance hits.

Build Option 3 – Turnkey System

Turnkey systems tend to be considered when performance is of paramount importance and the ATE switching subsystem can be defined in a static configuration with little need for reconfigurability. In these cases, test systems engineers often work closely with their product team to understand the requirements and architect a signal routing subsystem that is designed to deliver optimal performance. Once the switching subsystem layout and basic requirements have been defined, the decision must be made to complete the build in-house or work with a 3rd party to deliver the finished goods.

Build or Buy?

When debating in-house vs. outsourcing of a turnkey project, there are multiple factors that are to be considered. In terms of what consumes the engineers' time, there is typically a learning curve with which to contend. *Which switches are needed? What are their lead times? How are the RF interconnects between modules best made?*

The design and build of a one-off ATE can clearly take time, and as the pressure is on to have the system in use and the engineers returning to their other duties ASAP, it could be that only a minimal amount of documentation (bill of materials, schematics, test plans, etc.) will be created. Obsolescence mitigation planning may also be sacrificed in order to meet aggressive schedules. Accordingly, at a later date, if an identical ATE is to be constructed to meet an increase in production, the lack of detailed documentation will be a problem. Also, depending on when the identical ATE needs to be built, it might be that the original designer is no longer with the company, and the in-house / personal knowledge is no longer available.

In many cases, embarking on a second build without the correct level of documentation and experience can be as complex and time-consuming as the first time around.

It may also be the case that the system engineering team is focused on the design of the overall ATE system or even the design of the product to be tested, and there is no resource available to manufacture the signal routing box internally. If this is the reality, then it becomes more desirable to work with a 3rd party capable of distilling broad objectives and turning them into a finished and fully tested 'turnkey' product.

If the decision is made to work with a 3rd party to complete the project, the inclination could be to work with systems integrators who specialize in custom test system manufacturing. Assuming they have some knowledge in constructing RF subsystems, they will certainly be able to build and supply a one-off ATE. However, custom manufacturing houses can present the same risks that reside with in-house build, particularly if it is anticipated that additional units will be needed at some point in the future. A more practical solution is to consider partnering with an established volume manufacturer with a broad range of standard/off-the-shelf RF and microwave ATE products.

Pickering Interfaces' Turnkey Service

Pickering Interfaces designs and manufactures high-quality modular signal switching and simulation products in PXI, LXI and other formats. Frequencies range from DC to 110 GHz, and power handling of up to 700 W is available.

12x12 Microwave Matrix SP36T Microwave Multiplexer

Figure 4 – Above, example turnkey microwave switching systems from Pickering Interfaces.

Moreover, the company has a dedicated business unit focused on partnering services and product development. Accordingly, the design and construction of a turnkey, application-specific ATE switching subsystem is managed within Pickering's systems (including MRP) in the same way as the company's standard COTS products.

This means a turnkey product is assigned a part number within the MRP system along with version-controlled documents (including schematics and BOMs). Since the turnkey products are based on Pickering's standard product family, this also means that what is developed will fall under the company's obsolescence management processes and standard warranty program. Pickering is constantly monitoring for component obsolescence with the objective of keeping products in production for 20+ years. If a second build is required, this is easily accommodated. A strong track record with our suppliers enables us to extend 3-year warranties on the major components used in the solutions that are delivered.

This is, therefore, a greatly de-risked solution that many of Pickering's customers are experiencing today. This process has been streamlined to the level such that timeframes for each distinct project phase are outlined as follows.

Phase 1 – Proposal

This involves discussions with the customer (to really understand the intended application) and finetuning a requirements specification. These discussions include Pickering engineering and project management, and it is often at this point where recommendations are made to enhance manufacturability, performance and maintainability. A proposal will outline the build and include concept models, expected performance parameters, pricing and delivery schedules.

Phase 1 duration: 1-2 weeks

Phase 2 – Project Planning

Once the proposal has been accepted and a purchase order received the component parts needed for the build will be ordered. In this respect, the advantage here – as opposed to a company doing it in-house – is that Pickering is making RF/MW test equipment all the time and is likely to have many parts held in stock (or available on scheduled orders). Plus it has good access to components through trusted suppliers.

Pickering's project leader (the person who typically prepared the proposal) then briefs the design team as to the project requirements. Additional documents might be prepared, plus there might be further dialogue with the customer to clarify points.

Phase 2 duration: 1 week

Phase 3 – Design

This phase has three aspects:

- **Electrical/electronic hardware:** This establishes which components and sub-assemblies are needed and how they should interconnect.
- **Software:** Suitable drivers are needed.
- **Mechanical design:** This primarily concerns the chassis/rack, ergonomics, and cooling.

All aspects are modeled, and calculations (meeting power budgets, for example) are performed. Again, these are all things Pickering takes in its stride as the company has many standard parts and structures, as well as an extensive library of software drivers.

Through a close dialogue with the customer and in-progress design reviews changes to the requirements might occur. This may require returning to the proposal stage.

Phase 3 duration: 2-4 weeks

Phase 4 – Build

Of all phases, this is the one where outsourcing pays real dividends. To build an ATE in-house, a company would need a controller PCB, a means of interfacing with the components and possibly some ancillary boards. This could take up to six weeks per PCB for investigation, design, and manufacture. Pickering, on the other hand, has many standard parts which, if they cannot be used as-is, need only be modified. Also, if LXI is deemed the most suitable form factor, Pickering already has a standardized power supply and controller that provides the Ethernet connection needed to control the instrumentation.

Phase 4 duration: 2 weeks

Phase 5 – Test

All permutations of switch paths are tested to a mutually agreed upon Acceptance Test Procedure (ATP). Characteristics/results are measured (and supplied in the industry standard S2P format), and a test report is produced. This test report is available for review prior to delivery upon request. Customers can then use the provided S2P files for comparison purposes against their own incoming acceptance tests. Pickering can also provide a retest service for the ATE at a later date, if required.

Phase 5 duration: 2 weeks

Phase 6 – Final

This involves pulling together all the final material, including user manuals, datasheets, and technical drawings, plus of course, the test results. The switching subsystem is then delivered.

Phase 6 duration: 2 weeks

The Result

The above phases total 12-14 weeks. As mentioned, these are approximations based on typical projects, and every project is unique. For example, sometimes phase 1 (proposal) takes longer if more documentation is required. Conversely, phase 5 (test) can be as short as a couple of days. Again, it all depends on the complexity of the project.

As mentioned, it may be necessary to take a step or two back, sometimes all the way back to the requirements specification (phase 1), but those steps back would have had to be taken if the ATE were being designed and built in-house or if a systems house were to do the build. Pickering has gained a reputation of being very agile throughout the project build life cycle, operating as an extension to a company's engineering team.

For this reason, most projects have a degree of contingency built into the advised shipment schedule, where the contingency is available for use throughout any and all phases.

With Pickering Interfaces, most turnkey projects are turned around within a 12 to 14-week timeframe.

Also, the above phases are presented in isolation. Once the ATE is complete and delivered, the design will also be added to Pickering's portfolio as a standard product (with a user manual, datasheet and technical specifications made available for download). This means if the customer needs to order an identical ATE, they can do so easily.

Summary

The design, construction, and verification of an ATE is a drain on engineering resources. The extent of that drain will depend on the complexity of the ATE. Signal routing subsystems in particular are often afterthoughts in a system design even though they are a critical component of a test system.

Companies might be able to take the extremely flexible COTS chassis and module option, in which case it becomes a relatively simple plug-and-play exercise (particularly using PXI or LXI). They can buy standard products that, where Pickering's products are concerned, are supplied with datasheets and warranties and are subject to rigorous obsolescence management.

Or the company may need one or more modified modules – to avoid the performance hit that comes with too much external wiring – in which case Pickering is able to supply these. They are treated as standard parts (i.e., given part numbers, obsolescence management etc.), so if additional units are needed later, that is not a problem.

Importantly, Pickering even treats turnkey solutions as standard products, and as illustrated above, they can be supplied within 12 to 14 weeks. Here, particularly, the questions business owners and directors of companies making RF or MW products must ask themselves are:

1. *Could an ATE be designed and built in-house in such a short timeframe?*
2. *Even if it can, how many engineers will we need to divert from their core duties?*
3. *Is it the best use of their time? And, if we were to outsource the build to a systems house that promises a fast turnaround, do they have processes such as obsolescence management in place to give us peace of mind that we could return to them at a later date for an identical system?*

In summary, partnering with Pickering de-risks any ATE project. Whether the project can be satisfied with standard COTS products, modified COTS products or needs something as complex as a turnkey solution, Pickering can help. The company is platform agnostic and delivers the test capabilities that are of most importance to any OEM or RF and MW products that want to make efficient use of their in-house resources.

About Pickering Interfaces

Pickering Interfaces designs and manufactures modular signal switching and simulation for use in electronic test and verification. We offer the largest range of switching and simulation products in the industry for PXI, LXI, and PCI applications. To support these products, we also provide cable and connector solutions, diagnostic test tools, along with our application software and software drivers created by our in-house software team.

Pickering's products are specified in test systems installed throughout the world and have a reputation for providing excellent reliability and value. Pickering Interfaces operates globally with direct operations in the US, UK, Germany, Sweden, France, Czech Republic and China, together with additional representation in countries throughout the Americas, Europe and Asia. We currently serve all electronics industries including, automotive, aerospace & defense, energy, industrial, communications, medical and semiconductor. For more information on signal switching and simulation products or sales contacts please visit: pickering**test**.com

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