Replacement of obsolete measuring instruments in A&D test systems

Measuring instruments used in commercial test systems for applications such as testing of mobile radio base stations typically have a much higher lifespan than the test system itself. Some five to seven years of usage is normal prior to replacement. On the other hand, test systems for use in aerospace & defense (A&D) applications can have a typical lifespan of 25 years or even more. If standard measuring instruments with a lifespan that is significantly less than this time frame are used in such test systems, an obvious question is how to handle maintenance, repair, calibration and even replacement of the instruments that are no longer supported by their manufacturer.
Moreover, the test program sets (TPS) used in such test systems are generally certified, which makes it very time-consuming and costly to modify and reaccept them.

Migration strategies

In general, three strategies can be applied to solve this problem:

- Maintenance of the existing test system
- Migration with new instruments that emulate the discontinued instruments
- Modernization of the entire test system

In the first case, the test system's lifetime is extended through the use of parts or used instruments from the original manufacturer. This approach has lower costs, but the extension is limited to only a few years until a point is reached when the instruments can finally no longer be maintained or replaced.
Updating the entire test system is considerably more expensive and is usually done within major program updates or extensions. Benefits of this solution include a significantly higher life expectancy for the updated test system. Moreover, many tests run much faster after the process is complete and provide better throughput.
The migration approach is significantly more cost-effective. It involves replacing obsolete instruments with new ones that emulate their functionality and programming. The requirements for the new instruments revolve around the frequency and measurement range, dynamic range and noise characteristics of the instruments to be emulated as well as the test programs which ideally should not require any modifications. The requirement for complete code emulation means that the new instruments will understand the programming commands and also emulate the behavior as fully as possible. In the ideal case, the new instrument should always return the same "answer" as the instrument it is emulating.
Of course, there are some positive effects that result from migration to new instruments since state-of-the-art instruments are generally much faster and more precise. This allows improvement in the throughput as well as the yield since the higher measurement accuracy enables greater tolerance for the device under test (DUT).

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Remote control programming

When the GPIB interface for remote control of measuring instruments was initially introduced, it was common to emulate the front panel key codes with alphabetical and numerical codes. Later, simple abbreviations and mnemonics were used to make instrument settings, e.g. "CF" for the "center frequency" of the spectrum analyzer. Usage of delimiters was optional and upper- and lower-case letters were used to distinguish commands. Special characters such as "=" and "/" were allowed as part of the command.

To program the setting

Center frequency 3 GHz, Span 2 MHz, Marker to next peak, Blank trace C

the following combination was used:

CF3GZSP2MZKSKKSk

Each manufacturer had its own command definitions, which were naturally incompatible.

Two of the most prominent representatives of this early phase in remote control history were the HP8566A and HP8568A. They were used in very many A&D test systems.

The HP8566 spectrum analyzer

The next-generation HP8566B extended the number of characters per command and the space character was introduced for separating the command from the data. The semicolon character was used to separate individual commands and usage of upper- and lower-case letters to distinguish commands was abandoned. The sequence shown above was thus modified as follows:

CF 3GZ;SP 2MZ;MKPK NH;BLANK TRC

SCPI standard

A major step forward came about with the introduction of the Standard Commands for Programmable Instruments (SCPI) standard. This was a multi-vendor driven standardization of syntax and semantics for programming commands to be used in measuring instruments. Since that time, modern spectrum analyzers understand the sequence of settings given above in the following standard format:

SENS:FREQ:CENT 3GHZ;SPAN 2MHZ;:CALC:MARK:MAX;:DISP:WIND:TRAC:STAT OFF

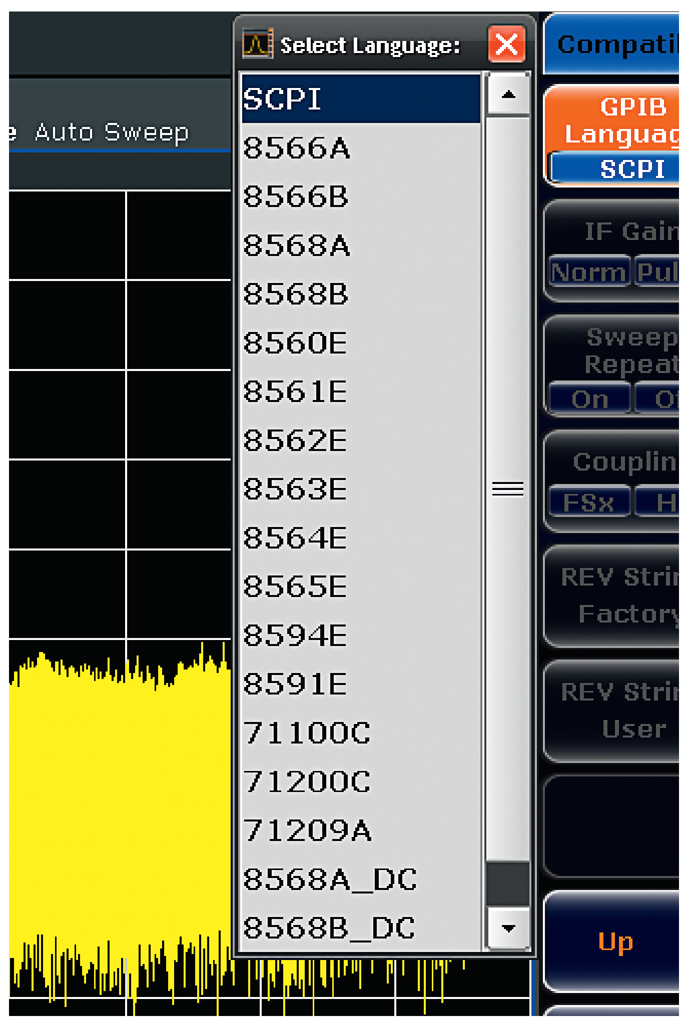
The introduction of the SCPI standard significantly lessened the problems associated with command incompatibility between instruments from different manufacturers. However, the situation is quite different when today's instruments are expected to emulate the earlier generations of instruments — this also involves switching from the SCPI parser to a legacy parser capable of interpreting the previous syntax and commands.

Command compatibility

During development efforts involving code compatibility, a number of challenges must be overcome in order to implement a suitable emulation mode. Simply translating the commands into the corresponding SCPI commands is usually inadequate.

Activation of emulation mode

As was mentioned, the emulation mode must be activated, which involves selecting the particular model of instrument to be emulated. Instruments from an earlier family might have a common set of legacy commands, but they can exhibit considerable differences in many areas.



FSV emulation mode: selection of analyzer to be emulated by the FSV

The existing control program controls the new analyzer just like the analyzer that was replaced. It is very important for the emulation to function in both directions, meaning the new analyzer must understand and be capable of processing the incoming commands and also deliver responses such as measurement or query results to the control program that are compatible with the emulated instrument.
In addition, activation of emulation mode enables proper adaptation to the different preset settings of the instruments or models to be emulated such as span, stop frequency, number of trace points, reference level, broadband coupling, etc.
Activation of emulation mode or native mode can also be handled programmatically, i.e. by means of a control command. This makes it possible for new control programs to take advantage of the features provided by state-of-the-art instruments in addition to their emulation capabilities.

ID string emulation and response formats
The response to a query of the instrument ID and firmware version must exactly match the response by the emulated model so the control program can reliably recognize the (emulated) instrument.
Properly formatted instrument responses to queries by the control program are essential for emulation of previous instruments, along with identical formatting of all parameters (integer, float, ASCII strings) and an identical number of characters.
When querying trace data, it is particularly important for the different query formats of previous instruments to be implemented so as to enable correct emulation. For example, the HP8566 provides four different formats for reading out trace data: an integer format, two binary formats and a string format.

Service request and status reporting
Service requests are messages the instrument sends to the controller when specific conditions or events occur that require a response by the controller. For example, this might be an indication that the analyzer has completed a sweep. The controller analyzes the different events and status messages using status byte queries.
Service requests and status reporting are defined in the IEEE488.2 standard. However, previous instruments implemented this functionality only partially and with somewhat different behavior. The responses of the status reporting (service requests) must be simulated as precisely as possible, including the response times and the related assignment of the status registers.

Save/recall and learn string
Many control programs take advantage of the instruments' ability to save, retrieve and load the current instrument settings. Here too, it is necessary to precisely emulate the different features of the instruments to be replaced. For example, the HP8566 analyzers can save the trace data and analyzer settings separately. Moreover, "Learn Strings" representing complete device setups in an 80 byte binary format recognized by the instrument's internal database can be read out and imported.

Markers and delta markers
Important measurement functions are implemented in spectrum analyzers using markers and delta markers. The behavior and the program control are defined in the SCPI standard – legacy instruments often diverge considerably from the standard as concerns their behavior so that markers and delta markers are not distinguished explicitly. For example, the marker query MKF? returns the delta marker frequency if the delta marker is currently active.

Conceptual differences in modern instruments
The HP8566 was the first spectrum analyzer with a synthesizer which also performed sweeps on a digital basis. All of the other parts of the analyzer were implemented using analog technology including resolution and video filters. The A/D converter digitized the video signal which was then presented on the display.
Modern spectrum analyzers directly digitize the IF frequency — an approach which offers considerable benefits in terms of performance, accuracy and reproducibility. A wide variety of filters can be implemented on a digital basis in order to fulfill the requirements of the latest mobile radio standards and also provide the capability to emulate analog filters with the shape factor used by obsolete analyzers.
The narrow filters are generally implemented using an FFT. The emulation implementation must also pay special attention to the overload immunity in order to further ensure compatibility with the previous instruments.

Wide range of emulations
The advanced spectrum analyzers, network analyzers and signal generators from Rohde & Schwarz all offer built-in emulation to ensure the highest possible code compatibility. This makes it feasible to use the migration approach in test systems if desired and replace obsolete measuring instruments.
In many applications, it is possible to continue using existing control programs without any modifications. Moreover, Rohde & Schwarz is committed to permanently improve the code compatibility of its spectrum analyzers, network analyzers and signal generators.

R&S®Legacy Pro: Compatibility matrix

Signal Generators

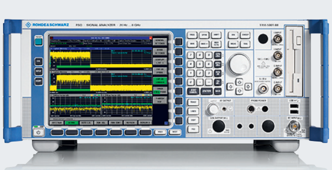
	R&S®SMA100A	R&S®SMB100A	R&S®SMBV100A	R&S®SMC100A	R&S®SMF100A
HP 8642	•	•	•	•	
HP 8643	•	•	•	•	
HP 8644	•	•	•	•	
HP 8645	•	•	•	•	
HP 8647	•	•	•	•	
HP 8648	•	•	•	•	
HP 8656		•	•	•	
HP 8657		•	•	•	
HP 8662	•				•
HP 8663	•				•
HP 8664	•	•	•	•	
HP 8665	•	•	•	•	
HP 8673					•
HP 8340					•
HP 8341					•
HP 8360					•
HP 83620					•
HP 83622					•
HP 83623					•
HP 83624					•
HP 83630					•
HP 8373					•
HP 83711					•
HP 83712					•
HP 83731					•
HP 83732					•
Agilent E4428C (ESG analog)	•		•		•
Agilent E4438C (ESG vector)	•		•		•
Agilent E8257D (PSG analog)	•		•		•
Agilent E8267D (PSG vector)	•		•		•
Agilent E8663B/D (PSG analog)	•		•		•
Agilent N5161A (MXG analog)	•		•		
Agilent N5162A (MXG vector)	•		•		
Agilent N5181A (MXG analog)	•		•		
Agilent N5182A (MXG vector)	•		•		
Agilent N5183A (MXG microwave)	•		•		
Aeroflex 202x	•	•	•	•	
Aeroflex 203x	•	•	•	•	
Aeroflex 204x	•	•	•	•	
Aeroflex 205x	•	•	•	•	
Anritsu 68017					•
Anritsu 68037					•
Racal-Dana 3102	•				•
Racal-Dana 9087	•				•
R&S®SMGU	•				
R&S®SMHU	•				
R&S®SML		•	•	•	
R&S®SMT	•				

R&S®Legacy Pro:
Compatibility matrix

Spectrum & Network Analyzers

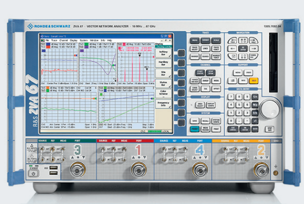
	R&S®FSP, R&S®FSU, R&S®FSQ, R&S®FSG	R&S®FSV	R&S®ZVL, R&S®ZVB, R&S®ZVA
HP 8560E	•	•	
HP 8561E	•	•	
HP 8562E	•	•	
HP 8563E	•	•	
HP 8564E	•	•	
HP 8565E	•	•	
HP 8566A	•	•	
HP 8566B	•	•	
HP 8568A	•	•	
HP 8568B	•	•	
HP 8591E	•	•	
HP 8594E	•	•	
HP 8594L	•	•	
HP 71100C/P	•	•	
HP 71200C/P	•	•	
HP 71209C/P	•	•	
HP 8753C/D/ES/ET			•
HP 8719C/D/ES/ET			•
HP 8720C/D/ES/ET			•
HP 8722C/D/ES/ET			•
HP 8510E			•
HP 8510SX			•
HP 85106D			•
HP 85107B			•
HP 8510XF			•
HP 85108A			•

Spectrum and network analyzers: a selection from our portfolio



R&S®FSQ

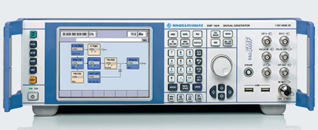
R&S®FSV



R&S®ZVA

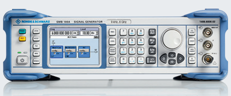
R&S®ZVL

Signal generators: a selection from our portfolio



R&S®SMF 100A

R&S®SMA 100A



R&S®SMB 100A

R&S®SMC 100A

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