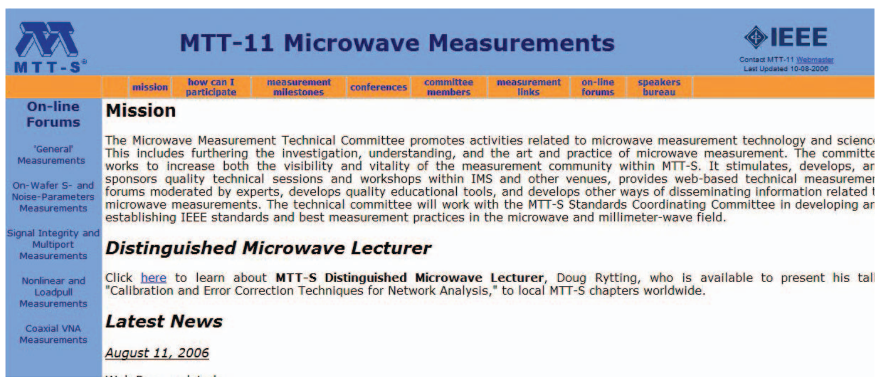
Member Benefits

The MTT-11 Web Page: A Multitude of Information Resources on Microwave Measurements

■ **Nuno Borges Carvalho, Kate A. Remley, and Dominique Schreurs**

The Microwave Measurements Technical Committee of the MTT-S (MTT-11) promotes activities related to microwave measurement technology and science. One of its main vehicles of information dissemination for general IEEE Members is its Web page interface (http://www.mtt.org/committees/mtt-11/index.html), which is a valuable tool for any microwave engineer who needs to be informed about measurements of radio, high-speed electrical, and microwave quantities.



The MTT home page

The Web page contains several important types of information for the IEEE community; for instance, a milestone paper Web page found here allows the reader to navigate through several important IEEE papers that are fundamental research works in the field and have revolutionized their area.

Most of the referred papers have a direct link to *IEEE Xplore* (http://ieeexplore.ieee.org), so that the reader can immediately download the paper from the net if he or she is an IEEE Member. This manner of presenting key technical material could reduce the time needed for research if the engineer is searching for a quick introduction to a given area.

The Web page also has an area dedicated to the members of the committee. There it is possible to find contact information for the members, each of whom is considered an expert in his or her area. Thus, the reader can quickly find someone who could help with specific measurement issues on a given topic.

This is further complemented by a page dedicated to our Speakers Bureau list, where the interested reader can learn about our appointed speakers and the talks they are presenting. At the time of this writing, MTT-11 has three speakers appointed: Dr. Jan Verspecht [Jan Verspecht bvba] and Prof. Andrea Ferrero [Politecnico di Torino], who are presenting a talk devoted to "Nonlinear Microwave Measurements: From Power Meters to Large-Signal Network Analyzers," and Dr. Michael Janezic [NIST], whose talk is devoted to "High-Frequency Measurements of Dielectric Substrate Materials."

It is also possible to see and hear the talk of MTT Distinguished Microwave Lecturer [2004–2006] Doug Rytting related to "Calibration and Error Correction Techniques for Network Analysis." This talk is now available to all net surfers in video streaming format.

Other pages on the Web site lead us to the most important conferences worldwide devoted to microwave measurements, and we also have links devoted to international institutions related to measurements.

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Last, but definitely not least, the most important feature and benefit of the MTT-11 Web page exclusively for IEEE Members is the online forum Web pages. MTT-11 members establish online forum Web pages, which are divided into the following five areas:

1) "General" Measurements
2) On-Wafer S- and Noise-Parameter Measurements
3) Signal Integrity and Multiport Measurements
4) Nonlinear and Loadpull Measurements
5) Coaxial VNA Measurements.

These forums provide a way to discuss measurement themes with top researchers in the area worldwide. IEEE Members simply sign up and are then given access to past and future posts of questions on measurement-related issues for some of the key topics of the day. At the moment, we have an average of 82 members per forum group and an average of 150 messages per area.

Table 1 presents a brief overview of forum statistics as of January 2007.

As an example, one post that received a significant amount of online discussion was related to "two-tier calibration." This was posted in the "On-Wafer S- and Noise-Parameter Measurements" forum and was initiated as a question on how to de-embed the probes and test fixtures on a probing station measurement.

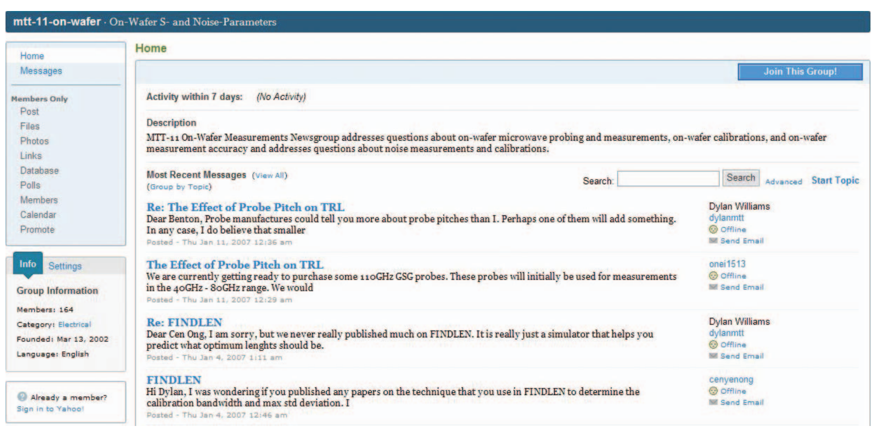
Another post that generated a high volume of online discussion traffic was the one about "ACPR estimation with multisines," in this case in the "Nonlinear and Loadpull Measurements" forum. This topic was devoted to a discussion on how to measure adjacent channel power ratio (ACPR) in a nonlinear power amplifier when the input signal is a multi-sine, and then how to infer that figure of merit for WCDMA signals.

Another discussion example from the "Coaxial VNA Measurements" forum was related to "TRL with 3-port symmetric devices," where the calibration of a two-port network analyzer for measuring a three-port circulator was discussed. In the "Signal Integrity and Multiport Measurements" forum, the moderator started a discussion on multiport topics such as calibration, accuracy verification, and on-wafer problems.

The "General" Measurements forum is mainly dedicated to providing general microwave measurement discussions. It deals with measurements of the microwave characteristics (e.g., S-parameters) of microwave and lightwave components and with the application of photonic techniques to microwave and millimeter-wave measurements. Moreover, it focuses on the metrology and measurement techniques for characterizing the broadband electrical properties of materials.

Other interesting discussions have centered around the name to adopt for the so-called "large-signal measurement instrument," which has had many different names depending on the manufacturer and the research institute were it is used. This discussion continues today in the "Nonlinear and Loadpull Measurements" forum. In the future, a new forum is to be available devoted to "Uncertainty in Measurements."

The MTT-11 Speakers Bureau list.



A snapshot of the "On-Wafer S- and Noise-Parameter Measurements" forum.

Table 1. Forum Statistics as of January 2007.

Forum Name	# of Members	# of Posts	Date of First Post
"General" Measurements	55	14	1 Feb. 2002
On-Wafer S- and Noise-Parameter Measurements	164	603	4 Dec. 2002
Signal Integrity and Multiport Measurements	45	24	2 Sept. 2004
Nonlinear and Loadpull Measurements	81	72	28 Feb. 2003
Coaxial VNA Measurements	61	35	20 Jan. 2003

Some of the future projects include the start of a wiki page devoted to measurements, where some definitions will be open to the engineering public in general. MTT-11 intends to continue to enhance the microwave measurements Web page, improving and increasing the benefits to all IEEE Members. Another project is devoted to building an archive of all the sponsored MTT-11 workshops where most of the talks will be available to IEEE readers.

If you have suggestions for the Web page or Web-based forums, please contact the webmaster, Nuno Borges Carvalho, at nbcarvalho@av.it.pt.

Benefits of ARFTG Membership

■ **Charles Wilker**

Who or what is ARFTG? This is a question that I receive quite frequently, even from people who have been working in the field for many years. The ARFTG appears to be one of those all too well-kept secrets but, for many, it should not be.

ARFTG is an acronym for the Automatic Radio Frequency Techniques Group. The ARFTG is a technical organization formed in 1972 which is interested in all aspects of RF and microwave test and measurement. Like the IEEE Microwave Theory and Techniques Society (MTT-S), the ARFTG is a community which brings together colleagues, experts, and vendors with a particular focus on RF and microwave test and measurement. The ARFTG is not a part of the IEEE, but an independent, international, nonprofit technical organization. Like the MTT-S, the ARFTG is a volunteer-run organization, operated exclusively for scientific and educational purposes. The ARFTG membership includes a broad, if eclectic, mix of government metrologists, academic researchers, and industrial practitioners. Like the MTT-S, the ARFTG provides a forum for the development of new technologies, methodologies, and instrumentation. The ARFTG organizes two conferences each year, both of which are technically cosponsored with the MTT-S. The ARFTG Spring Conference is held on the Friday of the International Microwave Symposium (IMS) week. (See Table 1.) A separate Fall Conference is scheduled at various locations the week following Thanksgiving (see Table 2). Like the MTT-S, the ARFTG supports and nurtures its student members, provides educational opportunities for its more senior members, and offers technical services specifically to the RF and microwave test and measurement community. Our members are always happy to discuss their latest research techniques and developments.

The ARFTG logo.

The most stimulating part of the ARFTG experience is the opportunity to interact one-on-one with colleagues, experts, and vendors in the RF and microwave test and measurement community. Whether your interests include high-throughput production or one-of-a-kind metrology measurements, complex systems or simple circuit modeling, small-signal S-parameter or large-signal nonlinear measurements, phase noise or noise figure, from dc to lightwave, you will find within the ARFTG a kindred spirit or maybe even an expert. There is always ample opportunity at every ARFTG conference for detailed technical discussions with others facing similar test and measurement challenges. The members of the ARFTG often find that these interactions are their best source of ideas and information for their current projects. So come and join us at our next conference, short course, or workshop. You'll find that the atmosphere is informal and quite friendly. For more information about the ARFTG, please visit our Web site at www.arftg.org.

The ARFTG Web site.

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TABLE 1. ARFTG Spring conference schedule.

	Date	Location	Topic
69th	June 2007	Honolulu	Addressing Metrology Needs for Future High-Speed Information and Communication Systems
67th	June 2006	San Francisco	Design and Measurements of High Power Devices and Applications
65th	June 2005	Long Beach	Measurements for Millimeter-Wave Applications
63rd	June 2004	Fort Worth	On-wafer Characterization
61st	June 2003	Philadelphia	Measurement Accuracy

The last five ARFTG Spring Conferences have been colocated with and held on the Friday of MTT-S IMS Week. The main conference theme has covered a wide variety of topics.

TABLE 2. ARFTG Fall conference schedule.

	Date	Location	Topic
68th	December 2006	Boulder	Measurement for Emerging Technologies
66th	December 2005	Washington, DC	Measurements of High Performance Devices and Applications
64th	December 2004	Orlando	Digital Communication System Metrics
62nd	December 2003	Boulder	Differential Measurements

The last four ARFTG Fall Conferences have been scheduled the week following Thanksgiving and include the ARFTG/NIST Measurement Short Course. The main conference theme has covered a wide variety of topics.

ARFTG History

The ARFTG was founded in 1972 to create a more cohesive voice for the RF and microwave test and measurement community to solicit support from the manufacturers of test instrumentation. The primary focus of the first few meetings was on the automation and calibration of network analyzers. In the early years, the ARFTG was more like a users' group than the professional measurement society the ARFTG would become. In fact, the early meetings were not a pleasant place for the representatives of the instrumentation manufacturers. The magic of these early test systems was embedded and hidden from the user in the software, which was then not available in source form. The ARFTG was formed to "help" the manufacturers realize and appreciate the needs of the users.

Why was there a need for automated network (and/or spectrum) measurements? When Hewlitt-Packard (HP) first introduced the 8410/8411 network analyzer test instrument and its RF test sets, RF components were typically octave bandwidth limited. They were not well matched, particularly above 12 GHz. There was no repeatable phase reference. There was no way to record the data short of scope photos and analog pen plotters. Sweeper band crossings were not pretty or repeatable. One was never sure which harmonic the instrument would choose. This made repeatable calibrations and phase stability a nightmare. And once those measurements were taken, the real task of referencing them to some known standard began. Finally, engineers would much rather a machine did these mundane bookkeeping tasks. All these problems were eventually solved with the help of the ARFTG. For an entertaining review of the early history of the ARFTG and the people involved, see [1].

Soon, however, issues such as measurement metrology, connector repeatability, noise and/or power measurements, and computer-aided design (CAD) became common topics at every ARFTG conference. The interests of the ARFTG have continued to expand with the interests of the RF and microwave test and measurement community and now include such diverse topics as: nonlinear measurements, production testing, temporal measurements, high-frequency fixturing, four- and six-port network analysis, and load pull measurements. Indeed, the broad range of ARFTG interests is reflected in the diverse nature of our membership and of the topics of our recent conferences. For the last 30 years, the ARFTG has been at the leading edge of the development of new RF and microwave test and measurement techniques and instrumentation. In 1987, the ARFTG became affiliated with the MTT-S and in 2000 formalized the relationship with a memorandum of understanding (MOU) which governs the coordination between the two organizations, especially between the IMS steering committee and the ARFTG Spring Conference.

In 2001, the ARFTG became incorporated as a nonprofit corporation. The ARFTG is an incorporated organization whose purposes are limited to education, scientific research, and publication of member research on a nonprofit basis as limited by Section 501(c)(3) of the Internal Revenue Code, in the field of automated RF network design and measurement. Our areas of involvement are: 1) to obtain and distribute information on how automatic RF measurement systems are being used, the types of measurements being performed, and the types of items tested; 2) to provide a forum for discussion and education on the interfacing of test equipment and on CAD techniques; and 3) to establish a mechanism to encourage sharing of software programs, ideas, and techniques. This is very similar to the nonprofit status of the IEEE.

ARFTG Membership

The ARFTG membership is a broad but eclectic mix of government metrologists, academic researchers, and industrial practitioners. There are currently over 600 members of the ARFTG; about half are technical participants and half are exhibitor participants even though many of them have significant technical expertise. The ARFTG is an international organization with over one-third of its technical members from outside the United States. Most international members attend their first ARFTG conference as part of IMS week, but many soon find the ARFTG experience to be of significant value to their projects. Annual ARFTG membership dues are only US$25 per year, and applications are printed on every conference registration form or can be found on the Web site at www.arftg.org.

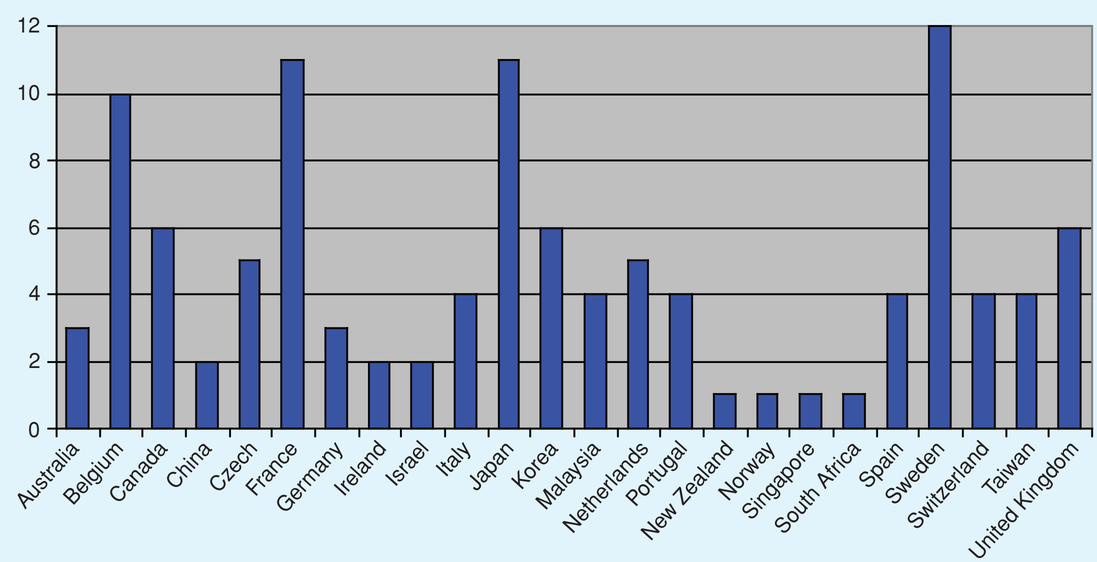
Oral technical sessions at ARFTG conferences are conducted in a single-track workshop style with papers on topical subjects both theoretical and/or practical, user and/or manufacturer, modeling and/or measurement. Shown here is the 61st conference in Philadelphia in June 2003.

ARFTG Microwave Measurement Conference

The ARFTG sponsors two conferences each year. These conferences are the principal and most important enterprise of the organization and serve as the focal point of the society's activities. They bring together the membership, both technical participants and vendors, to discuss their common problems, requirements, interests, needs, desires, and hopefully, solutions. These technical interactions occur during the formal oral presentations, as part of the interactive forum, in discussions with the vendors, and during informal discussions over coffee and/or a meal. Conferences are conducted in a single-track workshop style with papers on topical subjects both theoretical and/or practical, instrument user and/or manufacturer, modeling and/or measurement. A formal digest consisting of all of the conference papers is published and, since 2001, the ARFTG Conference Digest is also available through *IEEE Xplore*. All of the conference digests from the 19th through the 58th conference are also available on a single compilation CD-ROM, and all of the digests are in the process of being imported into *IEEE Xplore*.

The ARFTG Spring Conference is a single-day conference cosponsored with the MTT-S and held on the Friday following the IMS. The conference starts with a continental breakfast where the attendees mingle with one another as well as with the vendors. The technical presentations are conducted in a single-track workshop style, with ample breaks to rehash the technical presentations with the authors, to discuss test and measurement issues with colleagues, to view the interactive forum presentations, and to catch up on the latest from the vendors. Lunch is also an awards banquet where the best paper, best poster, and best vendor from the previous conference are acknowledged.

The ARFTG Fall Conference is technically cosponsored with the MTT-S and held during the week following the Thanksgiving holiday. The activities



ARFTG international membership. Over one-third of ARFTG's technical members are from outside of the United States.

begin on Tuesday morning with the ARFTG/NIST Measurement Short Course. This popular two-day course is an educational opportunity offered by the ARFTG in cooperation with the National Institute of Standards and Technology. This course is taught in a seminar style and provides both an excellent grounding in the fundamentals as well as exposure to the latest in RF and microwave test and measurement techniques taught by the experts. Basic measurements are covered on the first day, including: a microwave measurement overview, circuit theory, vector network analysis, test fixtures, on-wafer measurements, power, and noise. Additional in-depth topics are covered on the second day, including: phase noise, load-pull, digital modulation, and time domain techniques. Several tutorials specifically related to the conference theme are also covered on the second day and change from conference to conference. This course is not only for young engineers just starting out but also for experienced engineers who want to refresh or broaden their expertise. The conference itself starts with a continental breakfast on Thursday (and Friday) mornings, where the attendees mingle with one another as well as with the vendors. The technical presentations are conducted in a single-track workshop style, with ample breaks to rehash the technical presentations with the authors, to discuss test and measurement issues with colleagues, to view the interactive forum, and to catch up on the latest from the vendors. Dinner on Thursday evening is the awards banquet where the best paper, best poster, and best vendor from the previous conference are acknowledged and the society's major awards—the ARFTG Career Award, ARFTG Technology Award, and/or ARFTG Distinguished Service Award—are presented.

Dylan Williams (left) receives his Best Poster Award and Kate Remely (center) receives her Best Paper Award from Charles Wilker (right) for their presentations at the 61st ARFTG Conference in Philadelphia in June 2003. The awards were presented in Boulder at the 62nd ARFTG Conference Awards Banquet.

TABLE 3. The ARFTG board.

President	Greg Burns Northrop Grumman
Vice-President and Publicity	Leonard Hayden Cascade Microtech
Secretary	Nick Ridler National Physical Laboratory
Treasurer	Ken Wong Agilent
Exhibits	Joe Tauritz Universiteit Twente
Education	Dave Walker NIST
Publications	Brian Pugh Quorum Systems
Nominations	Mo Sayed (retired) Agilent
Standards	Bill Eisenstadt University of Florida
Electronic Communications	Ron Ginley NIST
Membership	Ray Tucker (retired) United States Air Force Research Laboratory
Technical Coordinator	Tom Ruttan Intel
Workshops	Dominique Schreurs Katholieke Universiteit Leuven
Awards	Uwe Arz Physikalisch-Technische Bundesanstalt
MTT-S Liaison	Chip Wilker DuPont

The ARFTG board of directors is composed of 15 volunteers, elected by the ARFTG membership, each of whom is elected to a three-year term.

ARFTG Board

I would also like to take this opportunity to acknowledge the volunteers whose efforts and dedication make the ARFTG possible. (See Table 3.) Often, they perform thankless tasks that take countless hours, and their only reward is the satisfaction of giving back to an organization that helped them sometime in the past. The board of directors of the ARFTG consists of 15 volunteers, each of whom is elected to a three-year term. The primary function of the board is to organize the two technical conferences, the ARTG/ NIST short course, and workshops and to publish the ARFTG Digest. Note that the composition of the current board reflects the eclectic mix of the membership as five members are government metrologists, three members are academic researchers, and seven members are industrial practitioners.

The most stimulating part of the ARFTG experience is the opportunity to interact one-on-one with colleagues, experts, and vendors in the RF and microwave test and measurement community, here shown during the interactive forum at the 68th ARFTG Conference in Boulder in December 2006.

ARFTG and Technical Innovations

The ARFTG has often served as a forum to bring together people from industry, academia, and government laboratories who share common test and measurement problems. The following are just a few of the many examples of RF and microwave test and measurement technical developments in which the ARFTG has played a pivotal role.

1) **Vector Network Analysis:**
Vector network analyzer (VNA)-based measurement systems, their automation, their calibration, and their measurement theory have been a major focus of the ARFTG test and measurement community from the society's inception in 1972. At almost every conference, at least one technical session has been dedicated to this topic. In 1993, the ARFTG began offering the ARFTG/NIST Measurement Short Course, which rapidly became the industry standard for an introduction to S-parameter and VNA measurements. Many new RF and microwave test and measurement engineers are exposed to the ARFTG for the first time just for this reason, learn the value of the ARFTG experience, and become regular participants. Doug Rytting, who many consider the father of the modern network analyzer, has taught this part of the workshop for many years and was awarded the ARFTG Career Award in 1998 for his many technical (and service) contributions to the ARFTG. The author found the course an excellent refresher and his numerous conversations with Doug valuable to his own work.

Doug Rytting, father of the modern network analyzer and recipient of an ARFTG Career Award in 1998, lectures about vector network analysis and the trade-offs between the 8-, 12-, and 16-term error correction models, at the ARFTG/NIST Measurement Short Course. Doug educated a generation of ATFTG test and measurement engineers about the proper operation and idiosyncrasies of vector network analysis and calibration.

2) **Time Domain:**
Time domain measurements—for example, TDR, TDT, and time gating—have also been a major focus of the ARFTG test and measurement community from the very early days. These techniques are important to those working in the microwave and/or high-speed digital world. They allow for the isolation of discontinuities and removal of adapter, cable, fixture, and test port match problems so that one can focus on the actual device under test. There have been many time-domain papers at ARFTG conferences and thus in the digest archives. Harold Stinehelfer, who many consider the father of time-domain transform measurements, holds the record for most papers presented at ARFTG conferences and was awarded the ARFTG Career Award in 1989. He also published MAMA's Notes that described many techniques for making better measurements using the time domain. Most of these techniques pioneered by Harold are now incorporated into the software of most modern VNAs. The author found MAMA's Notes and his numerous conversations with Harold valuable to his own work. For a photograph of Harold, see the excellent article on the early history of ARFTG [1].

3) **Microwave Probing:**
Microwave on-wafer probing, de-embedding, calibrations, and validity assurance of on-wafer measurements have been another major focus of the ARFTG test and measurement community. Most of the key developments for on-wafer measurements and on-wafer calibration standards were discussed and published in the ARFTG conference digests during the GaAs MMIC Defense Advanced Research Projects Agency (DARPA)-sponsored era. The commercial wireless marketplace as we know it today formed its roots in this key industry program, and the IC measurement and calibration methodology used today had its genesis in this early ARFTG work. Today, much of the microwave probing work has its focus in on-board probing for package and PCB characterization. Eric Strid, instrumental in developing practical and readily available microwave probes and probing techniques, has presented

Eric Strid (right) receives his Technology Award from Ray Tucker (left) for his advancement of the state of the art in microwave device wafer probing at the 29th ARFTG Conference in Las Vegas in June 1987.

Greg Burns presents the Technology Award to Andrea Fererro for the development and implementation of VNA calibration algorithms and nonlinear measurement techniques. The award was presented at the 68th ARFTG Conference in Boulder in December 2006.

Dylan Williams presents the Technology Award to Jan Verspecht for the development of the LSNA at the 60th ARFTG Conference in Washington, DC in December 2002. Jan shared this award with Marc Vanden Bossche and Frans Verbeyst.

many papers at the ARFTG through the years and was awarded the ARFTG Technology Award in 1987. Today, the ARFTG is in the middle of the action with many papers presented at recent conferences addressing on-board calibration techniques, measurement of packaged or PCB-mounted devices, and modeling techniques.

4) **Thru-Reflect-Line Calibration:** Thru-reflect-line (TRL) calibrations have become the accepted standard for accuracy to which all other calibration techniques are compared. The fundamental theoretical work and methodology developed by the NIST, university, and industry contributors has been presented over the years at ARFTG conferences, and many of the key reference papers are found in the ARFTG digests. Roger Marks and Dylan Williams, who were awarded the ARFTG Technology Award in 1994, and Andrea Fererro, who was awarded the ARFTG Technology Award in 2006, have made many technical contributions on this topic to the ARFTG through the years. The author found access to the experts essential to his work of calibrating his cryogenic wafer probe station.

5) **Large-Signal Network Analyzer:** Large-signal network analyzers (LSNAs) are becoming an indispensable tool used to characterize and understand the complexities of the nonlinear behavior of modern microwave devices. This understanding is essential to the efficient and effective design of devices with improved high-frequency performance especially at higher powers, e.g., high power added efficiency (PAE) amplifiers. These devices are an integral part of the explosion of the microwave and wireless market and its myriad of applications. Much of the original work on the development of the instrument, the interpretation of the measurement results, the development of calibration techniques, and the use of the measurement data to create high-frequency nonlinear models have been an integral part of every ARFTG conference for at least the past decade. Jan Verspecht, Marc Vanden Bossche, and Frans Verbeyst—the team that developed the LSNA—have presented much of their work at ARFTG conferences and were awarded the ARFTG Technology Award in 2002. In addition, the ARFTG hosts the NVNA (nonlinear vector network analyzers) user's group. This informal discussion group is devoted to sharing information and issues related to instrumentation utilized in the analysis of microwave circuits and systems that contain nonlinear elements. Topics include large-signal measurements utilizing NVNAs—e.g., microwave transition analyzers (MTAs) and LSNAs—as well as these measurements in conjunction with loadpull, sampling oscilloscopes, vector signal analyzers, and other test equipment used to perform large-signal measurements.

ARFTG Microwave Measurement Student Fellowship

An important aspect of the mission of the ARFTG is to promote and encourage young engineers to discover, explore, and ultimately choose the field of RF and microwave test and measurement. The ARFTG Microwave Measurement Student Fellowship provides financial assistance to graduate students who show promise and interest in pursuing research related to the improvement of RF and microwave test and measurement techniques. Applicants must be enrolled as full-time students at a suitably qualified institution of higher education and must be carrying out research as part of a degree program rather than just performing course work. The proposed research project must clearly involve RF and/or microwave test and/or measurement techniques and be supervised by a full-time faculty member. The faculty supervisor must be a member of the ARFTG, or alternatively, a member of the ARFTG must cosponsor the proposal. One or more awards of up to US$5,000 may be granted each year, based on available funding and on the number and quality of applications received. For more information on these awards, including how to apply for an award, please visit the ARFTG Web site, www.arftg.org. ARFTG Microwave Measurement Student Fellowship awardees are strongly encouraged to attend an ARFTG conference to present their work. One goal of the fellowship is to expose students and their faculty advisors to the ARFTG community in the hopes that our enthusiasm encourages them and that they might become active members of the society in the future.

ARFTG S-Parameter Measurement Comparison Program

A common problem of any RF and microwave test and measurement laboratory is to assess the certainty (or, just as importantly, the uncertainty) of its measurements. After calibrating your VNA, have you ever wondered if your calibration was valid? Have you ever been asked "How does one know that the measured results are correct?" It would be nice if there were an easy way to have confidence in your measurements. As the complexity of a modern VNA system increases, the number of calibration methods, the number of connector types, the number of measurement points, and the number of applications such as on-wafer probing continues to grow. It is possible that one correctly follows all of the procedures but still makes a bad measurement. Users need a way to verify that their VNA system, their calibration, and the measurement they have just made are good and thus have confidence in their overall measurement processes. The most common way that this is done is to provide traceability of the measurement system back to a common source, for example, a national laboratory. A better way to do this might be to use the ARFTG Measurement Comparison Program.

Every metrology laboratory has their collection of "gold" standard microwave artifacts or devices that are used for calibration. Supposedly, the S-parameters (and the uncertainty of the S-parameters) of these devices are accurately known. Transferring these known values to another calibration standard relies upon a properly functioning VNA, a valid calibration, and a good measurement. In practice, one set of standards is used to calibrate the instrument, which is then used to measure the S-parameters of the new set. This is how transfer standards are created. Uncertainties in the "gold" standards, malfunctions in the VNA hardware, errors in the calibration procedure, or poor or damaged microwave connectors can all yield nonrepeatable, nonvalid, and/or inaccurate measurements. So how can a metrology lab assess the "true" S-parameters of a microwave artifact or device? If the same artifact was measured by numerous labs and the results compared, then one has the ARFTG Measurement Comparison Program.

Uwe Arz receives his Best Poster Award from the author for the work he performed as the recipient of the first ARFTG Student Fellowship. This award was presented at the 59th ARFTG Conference in Seattle in June 2002. Uwe is now a member of the ARFTG board.

Bob Judish and Greg Burns receive their ARFTG Technology Award for the development of the ARFTG Measurement Comparison Program at the 62nd ARFTG Conference in Boulder in December 2003. Bob received a golf club from the ARFTG in honor of his second career as a golf bum, which he started shortly after his impending retirement from the NIST.

Making good, repeatable, accurate, and valid measurements on a modern VNA can be a daunting task. The ARFTG Measurement Comparison Program is designed to give a "snapshot" of your measurement capability. It is a free service offered by the ARFTG which allows participating laboratories to compare their network analyzer measurements to those obtained from other laboratories. Laboratory confidentiality is strictly maintained. There are many places to make mistakes or to take an inappropriate process step. The ARFTG MCP allows each metrology laboratory to use its own equipment, calibration, and measurement methods and offers participants a chance to compare the performance of their measurement process to those of other participants. The only cost to a participant is the time spent making the measurements and the cost of shipping the kit to the next participant. Given the increasing emphasis on measurement assurance, this program provides a valuable, cost-effective method for validating the participant's measurement capability. And so, now there is a way to know! For more information, please see [2] or go to www.arftg.org.

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[1] R. Tucker, "The history of the Automatic RF Techniques Group," *IEEE Microwave Mag.*, vol. 8, no. 4, pp. 68–74, Aug. 2007.

[2] R.A. Ginley, "Confidence in VNA Measurements," *IEEE Microwave Mag.*, vol. 4, no. 3, pp. 54–58, Aug. 2007.