



T2+2™ Market Overview

Radio Frequency and Microwave Test and
Measurement Equipment For Telecommunication
Applications

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Radio Frequency (RF) and microwave test and measurement equipment are tools used in tasks of testing, measuring, analyzing, controlling, calibrating, displaying and recording data in laboratory and other testing situations.¹ Because of this range of testing modalities, there is also a wide variety of technical equipment to meet these needs; examples of these tools include signal generators, spectrum analyzers, phase shifters, oscilloscopes, hybrid couplers, mixers, low-noise amplifiers, and low-pass filters. Additionally, the scope of application areas for RF/microwave products is nearly as broad as the number of technologies themselves,² and these tools are extremely useful in aerospace and defense, telecommunications, electronics manufacturing and science and educational applications. Telecommunications is the largest end-user market however, and these networks are exceedingly dependent on the functionality of electronic test and measurement instruments, as the minutest distortion of signals can result in failure to communicate.³

In addition to network testing, telecommunications components and related subsystems in wireless devices such as cell phones, are often tested with RF and microwave test equipment to verify not only impedance, but also signal amplitude, distortion, and jitter (phase noise).⁴ In terms of usage, radiofrequency test equipment is generally used in applications at frequencies of 1 gigahertz (GHz) and under, while microwave components are used in higher frequency applications. Because of this, there is generally a wider range of applications for RF test and measurement equipment and as the frequencies go up, these tools become increasingly expensive.⁵ In light of this, this report will touch on microwave equipment but focus primarily on RF test and measurement equipment, as these appear to be the dominant test and measurement tools used in telecommunication applications.⁶ While market sizes are hard to estimate, the following describes how we arrived at an estimate for the total test and measurement equipment market as well as the total RF test and measurement market. We estimate these market sizes to be approximately:

<i>Market Niche Size</i>			
<i>Market Size in Dollars</i>	<i>Growth Rate</i>	<i>Base Year</i>	<i>Detailed Basis for Estimate</i>

¹ “Test and Measurement Equipment.” March 2009. Industry Mart web site. <http://www.industrymart.com/articles/2009/03/test-measure-equipment.html> (accessed May 4, 2010).
² Heavens, Chris et al. “Future Outlook For The RF And Microwave Industry.” Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).
³ “Electronic Test & Measurement Market to Reach \$4.5 billion by 2010.” July 2007. Autotestnews web site. <http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/> (accessed April 28, 2010).
⁴ Reed, Greg. “As RF/microwave designs grow in popularity, so does the importance of validating and verifying their implementations.” May 2008. Test & Measurement World web site. http://www.tmworld.com/article/320628-Check_electronics_success_with_RF_microwave_test.php?q=microwave+market+billion (accessed April 28, 2010).
⁵ Anonymous, (Editor, Online Test and Measurement Magazine) in a phone conversation with Christopher Ahern on May 4, 2010.
⁶ “World RF Test Equipment Markets.” December 2009. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed May 4, 2010).

\$1.77 billion (overall test & measurement equipment market)	4%	2006	The revenue generated by the global electronic test and measuring equipment industry was estimated to be \$1.77 billion in 2006 and grow to reach \$2.33 billion in 2013, ⁷ representing a compound annual growth rate of approximately 4%.
\$1.35 billion (RF test equipment market)	2.33%	2009	Total global revenues for the RF test equipment market, which includes spectrum analyzers, signal generators, network analyzers, and power meters should increase from around \$1.35 billion in 2009 to \$1.48 billion in 2013, ⁸ which calculates to a compound annual growth rate of approximately 2.33%.
~\$400 million (RF test equipment used in communications applications)	2.38%	2009	In communication applications, global revenues for the RF test equipment market are estimated to be around \$400 million. This market segment is expected to grow to \$450 million by 2014, ⁹ representing a compound annual growth rate of approximately 2.38%.

The United States represents the single largest electronic test & measurement instruments market through 2001-2010. Sales in the United States are projected to reach 1.4 million units in 2010.¹⁰ In all other RF applications, aerospace & defense makes up around 27% of global revenues, followed by industrial and electronics applications at around 26%.¹¹

Market size and growth rate are a function of the number of people in the market and the anticipated rate of buying. As markets transition between emerging, growth, shakeout, mature, and declining, the basis for competition and the number of competitors usually changes, along with the factors influencing adoption of innovation. The number of and growth rate for customers suggests how many units might be sold.¹²

<i>Our Current View on the Phase of the Market</i>	
<i>Today</i>	<i>Trend</i>
Mature	Mature

⁷ "Test and Measurement Equipment." March 2009. Industry Mart web site.

<http://www.industryart.com/articles/2009/03/test-measure-equipment.html> (accessed May 4, 2010).

⁸ "RF testing market should expand in 2010." February 2010. Test & Measurement World web site.

http://www.tnmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).

⁹ "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required).

<http://www.frost.com> (accessed May 4, 2010).

¹⁰ "Electronic Test & Measurement Market to Reach \$4.5 billion by 2010." July 2007. Autotestnews web site. <http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/> (accessed April 28, 2010).

¹¹ "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required).

<http://www.frost.com> (accessed May 4, 2010).

¹² For a detailed discussion of the "innovativeness dimension," see Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995). For further readings related to market phases and innovation, see also James Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1996) and Vijay K. Jolly, *Commercializing New Technologies: Getting from Mind to Market* (Boston: Harvard Business School Press, 1997).

The global test and measurement industry has been in existence for decades;¹³ today, the industry is characterized by a few major players who control the majority of the test equipment market.¹⁴ The market for RF test equipment, in particular, is in a mature stage and is also characterized by strong competition.¹⁵ Despite this market maturity, investments in commercial communications are expected to be strong over the next few years, given the global expansion of third-generation (3G) and fourth-generation (4G) mobile cellular services, including Long Term Evolution (LTE) systems, which should continue to fuel opportunities for new RF and microwave test equipment. In wireless broadband applications, WiMAX also represents a growing market for high-frequency electronic test and measurement suppliers.¹⁶

Markets can also be described in terms of the basis for competition (best technological performance, best value or the price/performance tradeoff that best matches the end-users' preferences, lowest cost, or best availability or the ability to get the product quickly). This dimension helps to define the context in which a commercialization strategy must be developed.

<i>Basis for Competition in the Arena</i>	
<i>Today</i>	<i>Trend</i>
Best Value	Best Value

In commercial telecom applications, the market for test and measurement equipment appears to be driven by best value, as the top products are often determined based upon combinations of performance and value.¹⁷ Moreover, recent advances in RF and microwave test equipment and software are generally geared toward simplifying testing, increasing measurement speed, and improving accuracy, or a combination of the three.¹⁸ Another noticeable trend in both RF and microwave testing equipment is the integration of more test capabilities into single, one-box systems that can simplify overall testing processes.¹⁹ Additionally, end users are constantly looking to introduce cheaper and lighter products into their manufacturing facilities and test procedures.²⁰

¹³ “Western Europe General Purpose Test and Measurement Equipment Market: Total General Purpose Test and Measurement Equipment Market.” September 2008. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed May 4, 2010).

¹⁴ “An Interview with John Regazzi.” February 2010. Microwaves & RF web site. <http://www.mwrf.com/Articles/ArticleID/22404/22404.html> (accessed April 28, 2010).

¹⁵ “World RF Test Equipment Markets.” December 2009. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed May 4, 2010).

¹⁶ Heavens, Chris et al. “Future Outlook For The RF And Microwave Industry.” Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).

¹⁷ “Top Products of 2009.” Microwaves & RF web site. <http://www.mwrf.com/Articles/ArticleID/22251/22251.html> (accessed April 28, 2010).

¹⁸ “Measuring Advances in RF/Microwave Test Equipment.” October 2007. Microwaves & RF web site. <http://www.mwrf.com/Articles/Index.cfm?Ad=1&ArticleID=17221> (accessed April 28, 2010).

¹⁹ “RF testing market should expand in 2010.” February 2010. Test & Measurement World web site. http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).

²⁰ Mathew, Vijay. “Emergence of the Low-cost Test and Measurement Equipment market.” April 2007. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed May 4, 2010).

In each market there may be stakeholders and companies with significant market share that will influence the introduction of your technology. Some organizations or companies that will likely influence the introduction of this technology are the following:

<i>Examples of Major Competitors in the Arena</i>		
Competitor	Relevance	Web site
Agilent Technologies	Agilent Technologies is a leading provider of RF and microwave testing tools. ²¹	http://www.home.agilent.com
Tektronix	Tektronix has been developing test, measurement and monitoring devices for sixty years and its products include signal generators, spectrum and logic analyzers, and oscilloscopes among others. ²²	http://www.tek.com
Rohde & Schwarz	Rohde & Schwarz is a global manufacturer and supplier of electronic test and measurement equipment, as well as solutions for broadcasting, secure communications, and radio monitoring. ²³	http://www.rohde-schwarz.com
Keithley Instruments	Keithley Instruments is a developer and supplier of advanced electrical test instruments and systems from DC to RF ranges. Keithley's products are used in solving emerging measurement needs in production testing, process monitoring, product development, and research. ²⁴	http://www.keithley.com/
Aeroflex	Aeroflex is a high technology company that designs, develops, manufactures and markets a diverse group of microelectronic and test and measurement products used in supporting communication systems, networks, and automatic test systems. ²⁵	http://www.aeroflex.com/
National Instruments	National Instruments offers a range of RF and wireless test equipment which operates from DC to 6.6 GHz with up to	http://www.ni.com/

²¹ "RF & Microwave." Agilent Technologies web site. <http://www.home.agilent.com/agilent/application.jspx?nid=-34787.0.00&lc=eng&cc=US> (accessed May 4, 2010).

²² Tektronix web site. <http://www.tek.com/> (accessed April 28, 2010).

²³ Rhode & Schwarz web site. <http://www2.rohde-schwarz.com/> (accessed April 28, 2010).

²⁴ "Achieving Accurate and Reliable Resistance Measurements in Low Power and Low Voltage Applications." Microwaves & RF web site. <http://www.mwrf.com/whitepapers/Index.cfm?fuseaction=ShowWP&WPID=e448bd36-0ef7-4fee-a212-00a8f7d22a00> (accessed April 28, 2010).

²⁵ "About Aeroflex." Aeroflex web site. <http://www.aeroflex.com/about.cfm> (accessed April 28, 2010).

	100 MHz of instantaneous RF bandwidth. ²⁶	
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<i>Examples of Key Stakeholders or Networking Channels with Contact Information</i>		
Stakeholder	Relevance	Contact Information
Automated RF & Microwave Measurement Society (ARMMS)	Founded in 1982, ARMMS is an industry group dedicated to supporting all aspects of RF and microwave engineering and has expanded to cover diverse topics in Radio and Radar design and test, metrology, medical, and materials testing. ²⁷	Roger Hopper Chairman Roke Manor Research Email: roger.hopper@roke.co.uk http://www.armms.org
Automatic RF Techniques Group (ARFTG)	ARFTG is a technical organization that covers the diverse industry and field of RF and Microwave test and measurement. ²⁸	Ron Ginley ARFTG Vice President PO Box 228 Rome, NY 13442 Tel: 303-497-3634 http://www.arftg.org/
IEEE	The IEEE is a global organization that provides and develops standards, reports, and industry news in areas that include aerospace, telecommunications, electric power, and consumer electronics. ²⁹	3 Park Avenue, 17th Floor New York, NY 10016 Tel: 212-419-7900 http://www.ieee.org
The International Society of Automation's Measurement, Control & Automation Association	The Measurement, Control & Automation Association is an industry association that seeks to establish an information exchange and to promote cutting edge technology and developments. ³⁰	Grant Patterson Director Tel: 931-454-5213 67 Alexander Drive Research Triangle Park, NC 27709 http://www.isa.org
Semiconductor Equipment and Materials International (SEMI)	SEMI is an international organization that supports the manufacturing supply chains of microelectronic, display and photovoltaic industries. ³¹	3081 Zanker Road San Jose, CA 95134 Tel: 408-943-6900 http://www.semi.org/en/index.htm
National Institute of Standards and Technology (NIST)	NIST is a non-regulatory federal agency that seeks to promote U.S. innovation and industrial competitiveness through	100 Bureau Drive, Stop 1070 Gaithersburg, MD 20899-1070 Tel: 301-975-6478

²⁶ "RF Wireless and Test." National Instruments web site.

<http://sine.ni.com/np/app/main/p/ap/mi/lang/en/pg/1/sn/n21:1914,n17:mi> (accessed May 6, 2010).

²⁷ "About ARMMS." ARMMS web site. <http://www.armms.org/microwaveradiofrequency.php> (accessed April 28, 2010).

²⁸ "What is ARFTG?" The Automatic RF Techniques Group web site.

http://www.arftg.org/what_is_arftg.html (accessed April 28, 2010).

²⁹ "About Us." IEEE Standards Association web site.

<http://standards.ieee.org/announcements/PRNESR.html> (accessed April 28, 2010).

³⁰ The Measurement, Control & Automation Association web site.

<http://www.isa.org/MSTemplate.cfm?MicrositeID=544&CommitteeID=5236> (accessed May 4, 2010).

³¹ "Home Page." Semiconductor Equipment and Materials International web site.

<http://www.semi.org/en/index.htm> (accessed April 27, 2010).

	the advancement of measurement science, standards, and technology. ³²	http://www.nist.gov/
3G Americas	3G Americas is a trade organization established to unite mobile operators and manufacturers in the Americas to provide a single voice to represent the GSM family of wireless technologies – GSM, EDGE, HSPA and LTE. ³³	1750 - 112th Avenue NE, Suite B220 Bellevue, WA 98004 Tel: 425-372-8922 http://www.3gamericas.org/
GSM Association	The GSMA represents the world-wide mobile communications industry, including mobile operators, handset makers, software companies, equipment providers, Internet companies, and media and entertainment organizations. ³⁴	Seventh Floor 5 New Street Square New Fetter Lane London EC4A 3BF UK Tel: +44 (0)207 356 0600 http://www.gsmworld.com

Entry barriers are obstacles that remove customer segments from the market for some period of time. They limit the size of the addressable market in general or the market share that can be captured. These barriers must be overcome or avoided to have a successful market entry. Our work to date suggests the following entry barriers may prevent customer segments from buying this type of technology for some period of time.

<i>Market Entry Barriers</i>	
<i>Name of Barrier</i>	<i>Description/Why</i>
<i>Increasingly Complexity of Testing Requirements</i>	The test process has increasingly become more complex as the test and measurement industry is forced to address the concerns of chip manufacturers and decrease the cost of ownership of test systems. ³⁵ The advent of system-on-a-chip (SoC) devices has highlighted the need to effectively test a wide range of circuit types, including analog circuits, high-speed interfaces, embedded memories, mixed-signal circuits, and RF circuits. ³⁶ Additionally, the growing number of advanced networks is further straining the use of current testing modalities. ³⁷ This increasing complexity of measurement parameters, in addition to demand for lower cost units, may challenge firms to deliver increasingly sophisticated products at lower price points.
<i>High Capital Costs</i>	Capitalization requirements to enter and successfully attain a leadership position in the RF and microwave test and measurement industry are increasing

³² “General Information.” National Institute of Standards and Technology web site.

http://www.nist.gov/public_affairs/general2.htm (accessed May 6, 2010).

³³ “About 3G Americas.” 3G Americas web site.

<http://www.3gamericas.org/index.cfm?fuseaction=page§ionid=106> (accessed April 27, 2010).

³⁴ “About Us.” GSM Association web site. <http://www.gsmworld.com/about-us/index.htm> (accessed April 27, 2010).

³⁵ “RF testing market should expand in 2010.” February 2010. Test & Measurement World web site.

http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).

³⁶ Allan, Roger. “RF Instruments Must Cope With Massive Market.” January 2006. Electronic Design web site. <http://electronicdesign.com/article/test-and-measurement/rf-instruments-must-cope-with-massive-market11767.aspx> (accessed April 28, 2010).

³⁷ Heavens, Chris et al. “Future Outlook For The RF And Microwave Industry.” Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).

	dramatically, due to product complexity and the presence of entrenched competitors. ³⁸ This is a common occurrence with mature markets and may pose a barrier to entrants with insufficient capital.
<i>Conservative Nature of End-Users</i>	The conservative nature of some end-users, specifically exhibited in a hesitance toward adopting newer test solutions, has been a major challenge for vendors of modular solutions in the test and measurement market. As end-users have been accustomed to traditional solutions for many years, ³⁹ new or more advanced systems may face adoption challenges in initial product deployments. This challenge may only be a factor for well established applications, as unique, increasingly complex, or newer uses for such equipment may circumvent such a barrier.

In the test and measurement sector, one issue that continues to gain prominence is the growing complexity of testing regimes and the need to test and measure the wide variety of digitally modulated signals on the market. Today, engineers and technicians require test equipment that can measure many different signals, whether W-CDMA/HSDPA, CDMA/EVDO, WiMAX, or GSM/EDGE, and they must also be able to measure all these complex signals with extreme accuracy.⁴⁰ This growing complexity is likely to remain a major challenge for vendors with respect to successful market navigation for the foreseeable future. As test equipment vendors are under constant pressure to keep pace with the latest technology innovations, it has become necessary to implement multiple standards at the same time, which can increase costs and reduce profit margins.⁴¹

Market drivers are forces that strengthen or weaken the importance of end-user needs over time.

<i>Market Drivers</i>	
<i>Name of Driver</i>	<i>Why Significant</i>
<i>Expanding Use in Testing Consumer Electronics</i>	Higher demand for test equipment has been a result of increased focus on communications products and equipment. ⁴² Consumer devices are continually gaining more wireless capabilities and greater functionality. Given this trend, RF and microwave test equipment has correspondingly increased in importance as manufacturers of cellular, Bluetooth, and WLAN devices need to ensure their products meet customer demands and conform to the governing standards. ⁴³

³⁸ "An Interview with John Regazzi." February 2010. Microwaves & RF web site.

<http://www.mwrf.com/Articles/ArticleID/22404/22404.html> (accessed April 28, 2010).

³⁹ "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed May 4, 2010).

⁴⁰ Heavens, Chris et al. "Future Outlook For The RF And Microwave Industry." Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).

⁴¹ "Frost: Communication Sector Growth to Boost Revenues for Test, Measurement Equipment Market." October 2007. IHS Global Insight web site. <http://electronics.ihs.com/news/frost-test-measurement.htm> (accessed May 4, 2010).

⁴² "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed May 4, 2010).

⁴³ Reed, Greg. "As RF/microwave designs grow in popularity, so does the importance of validating and verifying their implementations." May 2008. Test & Measurement World web site. http://www.tmworld.com/article/320628-Check_electronics_success_with_RF_microwave_test.php?q=microwave+market+billion (accessed April 28, 2010).

<i>Expanding LTE Networks Drive Test And Measurement Needs</i>	Today, the need to develop and test handsets to meet the extreme performance requirements (increased data rates, higher spectral efficiency, and lower latency) of LTE (Long Term Evolution) networks will accelerate due to increased deployments of these next generation networks. ⁴⁴ This also holds true for network test and measurement as well, since LTE network testing is quite complex. During the development, manufacturing, installation, and maintenance of LTE infrastructure, changes and upgrades will have to be made to the test specifications, as well as how tests are conducted, ⁴⁵ likely further spurring development of new test and measurement systems and protocols.
<i>Opening Up of New Networks in Emerging Markets</i>	Developers of test equipment are becoming more motivated by expected growth in emerging markets. ⁴⁶ New networks in developing economies have now become major demand drivers for the electronic test and measurement instruments market. ⁴⁷
<i>Economic Downturn</i>	The global recession impacted a wide range of industries, including the communications test and measurement equipment market. End-users were very circumspect about their capital expenditure, and as the global economy declined, so did investments in test and measurement equipment. ⁴⁸ This slow down in demand is likely to only remain an issue for the duration of the downturn, and demand may trend upwards with the expected recovery.

Despite the maturing of the telecommunications test and measurement market, the establishment of new networks in developing economies and the need to upgrade existing communication infrastructure have become strong drivers of demand in the market.⁴⁹ It is expected that the number of smart phones that will run on these new networks will increase dramatically, thus significantly pushing the limits of the infrastructure. This is particularly anticipated in regards to new smart devices which are going to push a lot of data, translating into stringent latency requirements as the entire end-to-end performance and end-user experience will be very visible. Customer turnover is far higher with media rich services and, as a result, the requirement for simulation and scientifically analyzing and gathering data is far greater in these media-rich networks than in the past.⁵⁰

Here are some additional data and sources that can help you better understand the market.

<i>Name</i>	<i>Description</i>
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⁴⁴ “RF testing market should expand in 2010.” February 2010. Test & Measurement World web site. http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).

⁴⁵ Friedrich, Nancy. “Measurement Equipment Readies For LTE Rollout.” October 2009. Microwaves & RF web site. <http://www.mwrf.com/Articles/ArticleID/22044/22044.html> (accessed May 4, 2010).

⁴⁶ “Measuring Advances in RF/Microwave Test Equipment.” October 2007. Microwaves & RF web site. <http://www.mwrf.com/Articles/Index.cfm?Ad=1&ArticleID=17221> (accessed April 28, 2010).

⁴⁷ “Electronic Test & Measurement Market to Reach \$4.5 billion by 2010.” July 2007. Autotestnews web site. <http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/> (accessed April 28, 2010).

⁴⁸ “Movers & Shakers Interview with Atul Bhatnagar, CEO, Ixia.” April 2010. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed April 28, 2010).

⁴⁹ “Electronic Test & Measurement Market to Reach \$4.5 billion by 2010.” July 2007. Autotestnews web site. <http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/> (accessed April 28, 2010).

⁵⁰ “Movers & Shakers Interview with Atul Bhatnagar, CEO, Ixia.” April 2010. Frost & Sullivan web site (subscription required). <http://www.frost.com> (accessed April 28, 2010).

<i>Microwaves & RF</i>	<p><i>Microwaves & RF</i> is an online news and industry source that provides up-to-date articles, white papers, products listings and other related material dedicated to microwave and radiofrequency applications and industries.</p> <p>For more information please see the following URL: http://www.mwrf.com</p>
<i>Test & Measurement World</i>	<p><i>Test & Measurement World</i> is a print and online magazine that provides technology trends, product reviews, newsletters, blogs and other resources dedicated to the field of test and measurement.</p> <p>For more information please see the following URL: http://www.tmworld.com/</p>