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Subscriber Product Engineering

AT&T Network Ready Device Development Guidelines

Network Ready Lab
September 2011

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Revision History

Date	Revision	Description
12/15/2010	1.0	Changes to the sections based on EDO review
3/24/2011	2.0	Changes to various section for the first draft
4/6/2011	2.1	Changes to add two more sections.
4/27/2011	2.2	Changes to remove section 4.3 (SAR)
5/25/2011	2.3	Changes after review from EDO team

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Table of Contents

1 Scope of This Document

This Document, entitled " AT&T Network Ready Device Development Guidelines" provides guidance to wireless device developers who have limited exposure to the development of devices with wireless modules. This Document provides guidelines for building a wireless device to effectively and efficiently utilize the AT&T wireless network in order to deliver the best possible customer experience while maintaining the integrity of the AT&T network.

When devices are built for the first time to operate in wireless environments, there are quite a few key considerations for the device developer.

For example,

- If a device is built for gaming, the device may currently work in wired and WiFi environments; however, when the gaming device adds wireless access capability, factors such as varying RF conditions, mobility, multi-technology, and especially latency need to be considered when building the device.
- When a device is built to be a certain form factor (for example consumer electronics devices with wireless access), care should be exercised that antenna design and RF performance are not compromised due to form factor considerations.
- When packet data applications are designed, care should be taken to prevent applications from being aggressive with requests for an IP address or packet transmissions. This may result in excessive signaling traffic and frequent, short bursts of user data in the wireless network (RAN and packet core) that can be inefficient.

1.1 Audience

This document is written primarily for wireless device manufacturers, though others may find this information helpful. The Document provides an overview of the characteristics and salient factors of wireless technology that device manufacturers may need to consider when building products with a wireless component.

1.2 Key Assumptions

These guidelines are based on the following assumptions on the part of wireless device developers and manufacturers:

- Device developers have a background in building devices with some form of packet data capability and are now building devices for WWAN access as well; and
- Device developers understand that this Document is intended as an aid to building wireless devices and only offers suggestions and guidelines with no guarantee of device approval
- Throughout this document when we refer to wireless development, we include cellular technologies that are used in AT&T Mobility as part of that definition.
- When you see references to 2g, 3G, 4G, 4G LTE, HSDPA, etc. those references refer to technology; they do not refer to speed.

1.3 Contact Information

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Please reference “AT&T Network Ready Device Development Guidelines” in the subject line of your e-mail.

1.4 Resources

Public

FCC website	www.fcc.gov
PTCRB website	www.ptcrb.com
CTIA Test Plan for Mobile Stations Over the Air Performance	www.ctia.org/certification
AT&T Emerging Devices website	www.att.com/EDO
PCI sig specifications	www.pcisig.com/specifications/pciexpress/
GSMA Embedded Module Guidelines	www.gsmworld.com/our-work/mobile_broadband/embedded_mobile/iindex.htm

AT&T

AT&T Terminal Unit & Accessory Technical Acceptance Process
AT&T Document Number 14782

AT&T Device Requirements
AT&T Document Number 13340

Note: Prior to receiving some of the documents referenced above, a signed non-disclosure agreement (NDA) with AT&T may be required to receive some of the documents referenced above prior to receiving these documents. To request to sign an NDA with AT&T, please write to edoteam@att.com .

2 Design Criteria Overview

The following sections provide an overview of various criteria to consider when designing wireless devices and generally discuss issues associated with design area, the rationale as to why certain factors have to be considered when building wireless devices, and suggestions on how a successful design can be achieved.

3 Advanced Antenna Design

For small form factor integrated devices, it is always a challenge to design an antenna to work on multiple bands. For example, for an LTE technology enabled mobile device, the antenna might have to cover LTE bands 17 and 4, GSM/UMTS bands 850 and 1900, and UMTS bands 900, 1800 and 2100.

A simple PIFA antenna is not able to achieve acceptable performance across multiple bands. Developers need to consider more advanced antenna design technologies, such as parasitic antenna components, fractal antenna design and other antenna design methods. Determining antenna gain and VSWR specifications is highly recommended as the first step of antenna design. According to radio output power/receive sensitivities, as well as AT&T TRP/TIS intermediate channel requirements, developers should be able to determine an optimum antenna gain specification. The antenna gain specification will be more accurate with consideration of cable loss and load pull loss

Active antenna design can provide wide bandwidth for multiband support. Tunable antennas can:

- improve efficiency and enable smaller antenna for the device to operate at peak performance;
  and
- set the band selectively while maintaining the antenna gain and size, allowing the antenna to cover the expected operating frequencies of an LTE device by changing its bandwidth and center frequency instantaneously at any given time.

The performance of the Antenna can be impacted by the device chassis and structure around the antenna or by any metallic painting close to the antenna.. As a result, it is important to measure RF performance before making change in mass production.

4 Antenna Mismatch

In a radio system, from the transceiver to the antenna, RF components are typically designed to be connected in a series cascade configuration. All the components are designed to function most effectively at 50 ohms. Loss due to mismatch would occur at any point where a component RF input or RF output impedance is not equal to 50 ohms. For example, if the main power amplifier is connected to a mismatched impedance line more DC power will be consumed to make up for the impedance mismatch, and the amplifier linearity will be degraded significantly.

Also, if the impedance at the antenna connector on the radio module is not 50 ohms, performance will be degraded. Any detuned antenna would cause severe degradation in RF performance. When antenna VSWR increases, the power radiated by the antenna will decrease, and the power reflected back from antenna will increase; as a result, the power that the module delivers will increase too. Because of the increase in delivered power, the current consumption will increase accordingly. Due to antenna detune, using an internal antenna instead of an external antenna will be more challenging when integrating the radio and antenna into a device. We highly recommend that the antenna engineer is closely engaged in the integrated device development from a very early stage to ensure good antenna performance, especially during the device hardware architecture definition.

5 Wireless Interference Mitigation

There are many sources that can cause interference when developing a wireless product. This section provides an overview of some of the more common sources and advises how to mitigate them.

5.1 Problem Statement

Wireless networking transceiver or receiver designs may experience a significant amount of interference. Interference is the unwanted electrical or electromagnetic energy that degrades the quality of signals and data in a system. There are numerous contributors to the interference induced on systems from both external sources and internal sources. External noise may be channel noise which includes relatively flat white noise. The internal sources of interference have more of an impact on a system so that design engineers are more concerned with them. Internal noise originating from clocks and other internal devices may include noise having distinct non-flat frequency components.

For example, in a notebook computer internal sources such as clocks (e.g., display dot clock, data clock) and other components located on the wireless platform may generate signals that can cause significant interference within the wireless networking receiver. Based on the location of the interference measured in the spectrum, the source of the interference can often be identified. This internal platform noise may also be periodic and change frequency with time. The variation of the interference observed can change from component to component and affects the overall system performance differently.

In the development of an integrated device, it is important that the device meet certain legal EMI and wireless performance requirements, particularly if you are planning on shipping your device outside of the U.S. Some of the wireless performance requirements are specific system level emission requirements for unintentional noise coupled onto the system antennas. These levels need be specified before product development so that the device can meet the performance requirements for wireless technologies and improve the overall customer experience.

5.2 Design Guidelines for Noise Mitigation

There are two ways to properly minimize electromagnetic emissions during product development:.

- **Source Suppression**
  Minimizes emissions at the board level with high speed CAD rules and PCB layering strategy. Since most EMI is emitted directly by the PCB or is primed by PCB coupling, this approach is the most useful in reducing weight and cost due to EMI shielding, while increasing signal quality and IC stability.
- **Localized Shielding**
  Captures the remaining electromagnetic emissions from an IC or PCB structure.

For many EMC reasons, the best source suppression is achieved with a single PCB system. Transferring clocks and data buses between more than one PCB (e.g. separate row & column PCBs) has inherent risks and requires special design considerations, both electrically and mechanically.

- First, the PCB board stack-up should be defined to provide specific phase coherent High Speed Group channels for routing of high speed signals.
- Second, these High Speed Group channels should be referenced to a contiguous ground plane and employ proper Mircrostrip or Stripline design.
- Third, clock and data traces should be kept away from the edge of the ground plane and spacing of clock and data lines to other traces need be kept to at least three times of the trace width. Small spacing between traces and planes is becoming increasingly important for interference mitigation.

Next, during the design of the PCB layout, it is absolutely critical that clocks are isolated and care is taken to route RF and digital signals properly. Harmonics of clock frequencies that fall into the receive band are one of the major interference sources to WWAN radios. Four clock parameters can be changed to minimize impact of interference to WWAN receive bands.

Those clock parameters are:

- **Frequency**
  Small clock frequency shifts should be sufficient to avoid even wideband wireless broadband channels at higher frequencies.
- **Spreading**
- **Rise/fall times**
- **Amplitude**

Next, good grounding is mandatory around all RF and digital circuits and is important especially for shield tracks. This is becoming much harder to achieve with higher density boards where interfaces are line to line and there is less room for ground vias. With the advent of modules with mixed signals, care must be taken to route into and out of these modules to avoid noise coupling.

Other interference mitigation methods include:

- **Filters**
  Can be added to achieve significant improvement on noise mitigation. However, aggressive filtering of the signals might compromise signal integrity. So a balance needs be achieved between quality of the signal (rise time, fall time, etc) and the harmonic content. Shielding such as RF gaskets and copper tape can be used.
- **Shielding**
  Shields have to be properly implemented; otherwise, the effectiveness of the system will be greatly reduced and subject to higher interference.

5.3 Noise Measurement

Measuring system noise allows developers to evaluate their components to determine if they have the potential to produce interference that may impact the wireless devices. Noise measurements provide an indication of the amount of system noise being picked up by the antennae with the current configuration of the system.

Measurements should be taken in an RF shielded enclosure or chamber with no outside RF interference sources present. The shielding effectiveness of the chamber or enclosure should allow the developer to measure signals as low as -130 dBm. A calibration of the test setup must be done to ensure accurate measurement results. Near field emissions test is very helpful to pin point the source of the interference and any EMC design flaws that exist in the board's overall design, avoiding a negative impact on a system's EMI compliance and wireless performance.

It is important to find and to isolate these design flaws (both from a PCB layout perspective and a mechanical design perspective) early in the development cycle, thereby, allowing time to correct without impacting schedule.

5.4 Summary

As functionality increases in wireless devices, measuring interference becomes more complex because of the multiple permutations and combinations of features being on simultaneously. It might not be realistic to test all combinations. It is more feasible to focus testing on high user scenarios and use shortened testing for the other scenarios.

It is crucial that the RF engineers work closely with the mechanical engineers during early design phases. If noise testing begins only with assemblies that are near the final design phase, it will be extremely difficult to make mechanical changes so late in the design cycle.

During integrated wireless device development, it is imperative that noise mitigation design guidelines need be followed and interference levels measured are at each design stage to ensure the device meets regulatory and wireless performance requirements.

6 Antenna Debugging Tools and Procedures

This section provides an overview of some key tools, materials, and procedures for debugging issues during the wireless device development cycle.

6.1 Key Tools

- Soldering Station
- Copper Tape
- Inductor/Capacitor Kit
- RF Spectrum Analyzer
- RF Signal Generator
- RF Power Meter
- RF Power Supplies
- Network Analyzer
- Network Emulator Call Box for Parametric Measurements
  i.e.: R&S CMU200 or Agilent 8960

6.2 Debugging Receivers

Many variables can affect the RF sensitivity performance of wireless receiver chains. Some of the common causes of poor RF receiver sensitivity include:

- Poor receiver architecture selection/design;
- Improper receiver RF calibration from the factory;
- Direct coupling of noise within the layout of a PCB; and
- Radiated noise emitted from the PCB that is received by the antenna

Considering the increasing number of supported bands, modes, and features of a modern day wireless device, any noise generated from power supplies, or clock harmonics of peripheral circuitry can affect adversely the receiver performance of a wireless device.

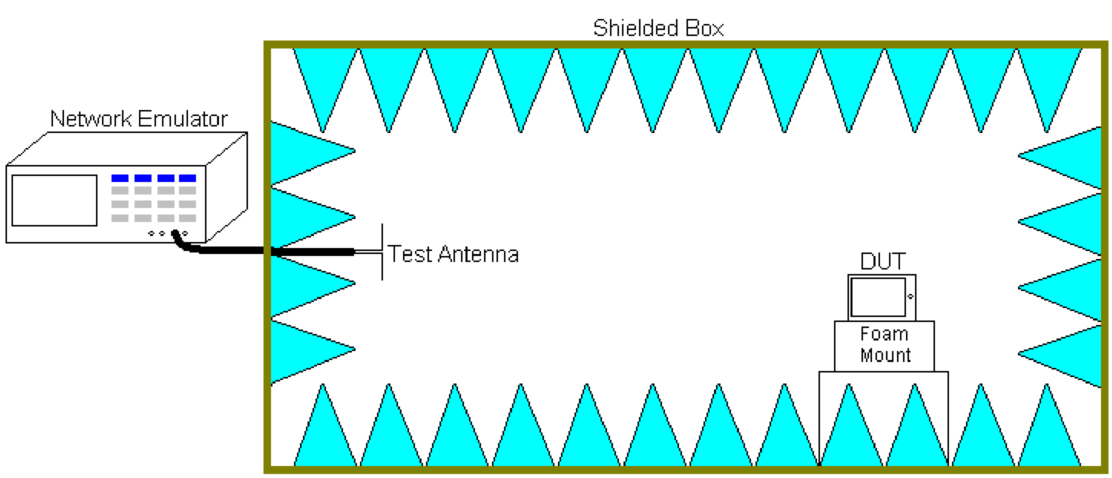
An assumption of this guideline is that a certified AT&T/PTCRB/GCF module is being used. Therefore, this guideline will concentrate on the debugging of noise coupled to the device over the PCB and the noise radiated back into the antenna.

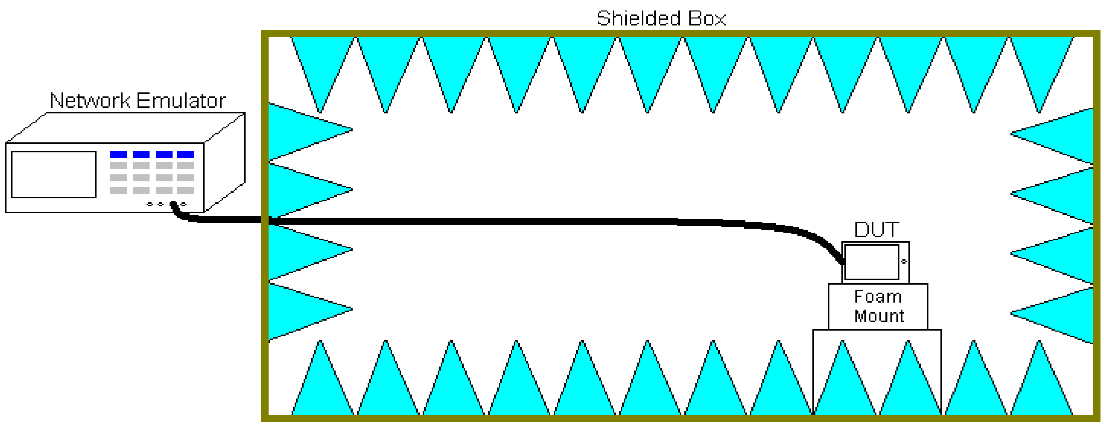
6.3 Conducted Measurements vs. Radiated Measurements

Conducted measurements are taken with a device physically cabled from the antenna feed point to a network emulator. A radiated measurement is taken in a shielded/screened room using the device's own antenna and connected over the air to a network emulator through a simple dipole/monopole antenna connected to the RF port of the network emulator. Full band sweeps can be performed using the network emulator/call box to hand off the DUT from band to band, and channel to channel.

In performing radiated measurements, care needs to be taken in the selection of a screen/shield room and box. Live network RF carriers as well as PCs/LCDs can cause false positives on a device being tested in an improperly shielded environment.

The following are typical setups for a device being tested in a conducted or radiated environment:





6.3.1 Conducted Measurements

Conducted measurements are used to capture the direct noise coupled by the PCB onto the module. Issues that are found in conducted measurements will ultimately show up in a radiated environment.

For any Radio Access Technology, a baseline of the receiver sensitivity across the entire frequency band(s) of operation should be taken. For this baseline, receiver sensitivity measurements should be verified across the entire frequency bands over a cabled connection, and not through the antenna. This test should be performed with the antenna completely removed, and a properly calibrated cable connecting the antenna launch point to a network emulator. This baseline will capture the PCB related design issues affecting receiver sensitivity performance from noise sources like unshielded voltage switching regulators.

As a best practice, for optimal conducted receiver performance, adhere to trace/component keep out and grounding footprints as provided by the module vendor during the initial PCB design process.

6.3.2 Radiated Measurements

GSM DUT self-reported RxLev and RxQual measurements can be mapped to received power and BER values. Assuming that the receiver was calibrated properly in the factory, using the RxLev and RxQual values allow for radiated testing of GSM to be performed with out exact calibration of path loss between the device and the test antenna attached to the network emulator. Target for GSM BER is 2% or an RxQual of 4. Once a device is put into a call with the network emulator, a search is performed for an RxLev which provides a RxQual. Any RxLev values found in this test greater than 8 is a specification failure.

WCDMA radiated BER measurements cannot rely on DUT reported values. Therefore the careful calibration and meticulous handling of how the device is fixtured within the test environment is needed to perform a RMC BER sweep. Additionally, path loss changes across frequencies, so the tester should calibrate for several intermediate channels between Low, Mid, and High channels.

One technique for calibrating is to use a non-working built-up model of a device with a Power Meter/Spectrum Analyzer connected to the point where the RF feed usually would exist. Next, a signal generator then should be connected to the RF port to which the network emulator will be connected. This set-up should then be calibrated like a simple cable calibration.

Another technique (similar to the one above) would be to use a working model of s device with a field test menu to measure the radiated received power generated by a network emulator. Conducted Factory Calibration of the module should be tested prior to assure that the module is accurately phased.

WCDMA RMC BER measurements should be swept across frequencies per bands. Also, the sensitivity level at which 0.1% BER for 12.2k data rate should be found per channel. This technique will have the highest sensitivity accuracy, and will most closely mimic operation during a normal OTA connection. The drawbacks to this method include the difficulty in calibrating path loss as well as the time needed to sweep per channel/per frequency band.

Most network emulator vendors will provide some type of control program for automation of BER Searches as well as channel handoffs for the frequency sweep. Additionally, most vendors will provide instructions on how to manually perform a BER search. Consult those vendor application notes/services during the selection of an adequate network emulator.

6.3.3 Building a Sweep Matrix

Many times, tagging the culprit of noise may be as easy as identifying the frequency channel affected. Often the frequency of the channel affected is simply a harmonic of a clock running on the PCB. A simple exercise is to determine the clock tree of the device, focusing on high speed clocks related to the application processor, LCD/video, camera clocks, transflash, etc. Specific areas to target are hinges, board to board connectors, flexes, and display frames.

Once all sources of interference have been identified, the easiest method of analyzing the effects of each possible interferer is to make a test matrix of sweeps. Below is an example of a sweep matrix. Note that because WCDMA is not a Time multiplexed technology, poor transmitter performance can actually bleed into a receive band and affect receiver performance.

			Desired Receive Band													
			WCDMA BAND 1 RX		WCDMA BAND 2 RX		WCDMA BAND 5 RX		GSM RX		EGSM RX		DCS RX		PCS RX	
			Conducted	Radiated	Conducted	Radiated	Conducted	Radiated	Conducted	Radiated	Conducted	Radiated	Conducted	Radiated	Conducted	Radiated
Possible Interferer	TX	WCDMA TX LOW POWER														
		WCDMA TX MAX POWER														
	Peripheral	LCD ON														
		Proximity Sensor														
		Metal plate														
		External Video Out														
		Transflash														
		Bluetooth														
		WLAN														
		GPS														
		Main Camera														
		Front Facing Camera														
		Charger														
		Dock/Car Kit														

Not Tested
Work In Progress
Completed and Clean

6.3.4 Conclusion on Receiver Debug

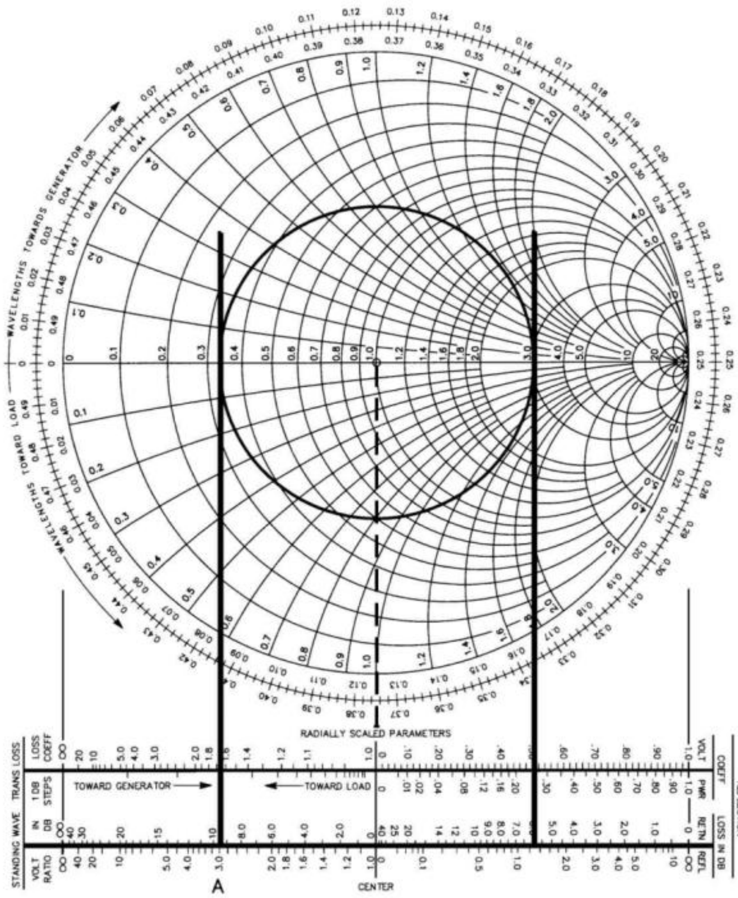
With the above receiver sweep matrix, the goal is to isolate and identify the signal sources which will affect the receiver sensitivity performance of the device. By using this method, costly surprises like an unexpected TIS failure at CTIA can be reduced because the radiated receiver performance can be benchmarked prior to submission.

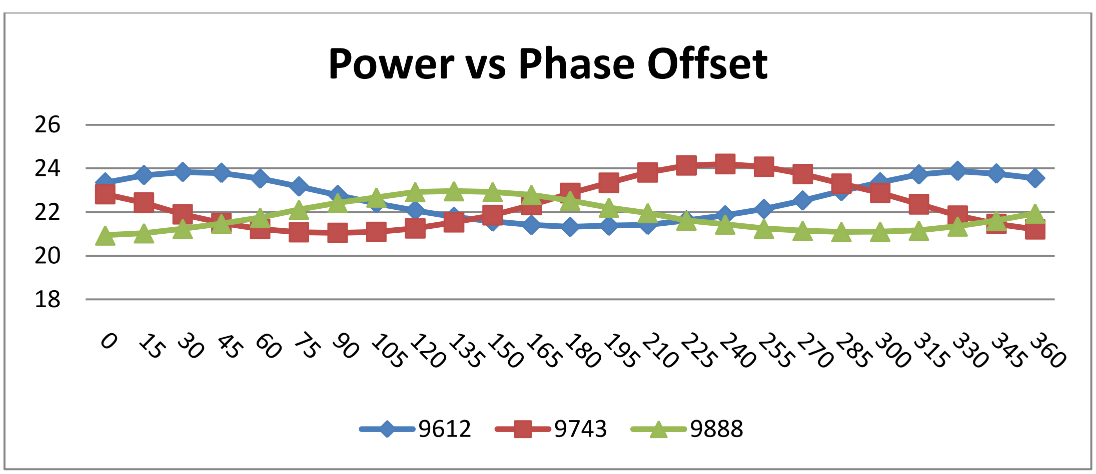
6.3.5 Transmitter Debug

Assuming that the device design incorporates the use of a pre-approved module, RF transmitter parametric performance should meet AT&T/3GPP requirements. However, be aware that every tenth of a dB counts in meeting TRP specifications, because the uplink is power limited based on the class of transmitter used.

To meet the requirements of TRP, a common practice for antenna tuning is to perform a load pull on the output of a module to find the best quadrant in which to match the device's antenna

If an accurate VSWR circle can be maintained, when swept across the phase, the output power of a module is often times sinusoidal with respect to the phase. Please see the following diagram for a 3.0 VSWR circle on a Smith Chart, and a phase sweep performed on a device with VSWR set to ~ 3


WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD
RADIALLY SCALED PARAMETERS
TOWARD GENERATOR
TOWARD LOAD
A
CENTER

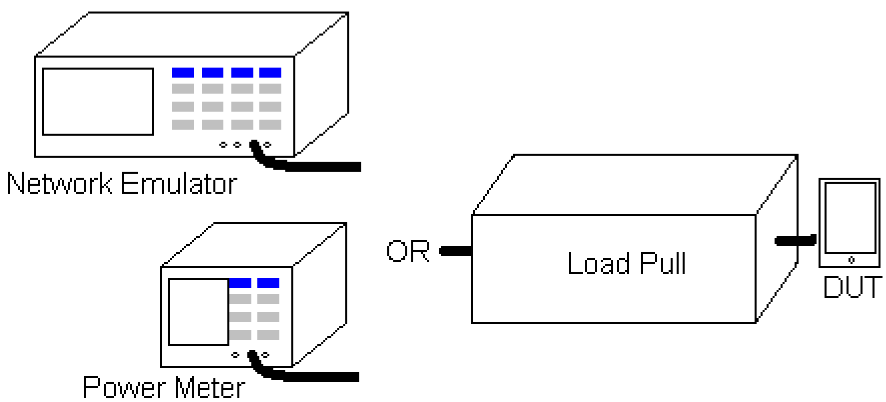

Power vs Phase Offset
26
24
22
20
18
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
9612
9743
9888

6.3.6 Load Pull System and Setup

A load pull system consists of extremely high precision mechanical tuners which can sweep and rotate around different VSWR circles. Thankfully, modern day electronic / computer controlled tuners are available. With the use of calibrated varactors and transmission lines, these tuners have almost perfect repeatability and one can recreate the exact impedance to improve testing.

The difficulty in load pulling a device is in how to recreate and to accurately measure the impedance on a network analyzer once a module's transmit "sweet spot" has been found. The "delay" added by the small coax cable should be accounted for when finding the correct impedance presented to the module when the "sweet spot" is discovered.

Once a module is properly cabled to the DUT end of the load pull, the output of the load pull system should be terminated into a power meter set to measure the power of the RAT of interest. The Load pull should be swept across VSWR/Phase, and measurements should be taken on a power meter. A typical load pull setup can be seen in the following diagram:



7 Wireless Network Design Fundamentals

This section provides an overview of packet data behavior in wireless networks which will be a key factor when designing a wireless device.

Internet Protocol (IP) has been used extensively in various wireline network environments offering a variety of data services with various traffic characteristics. The most common use of IP has been over LANs, where several types of link level protocols are used to carry IP traffic (the most common one being Ethernet).. An extension of the LAN using WiFi allows the user to move around in larger environments untethered while still providing access to data applications. LAN and Wireless LAN together can support IP on the network layer which allows a wide variety of applications built on the higher layer protocols over IP (TCP, UDP, etc..).

Wireless networks provide another link-level alternative to offering various services over IP. With the current 2G/3G technology and 4G LTE technology, wireless networks offer a complete solution for addressing, security, paging, mobility, accounting and authorization and so on for a wide variety of services.

The IP suite of protocols is built with the assumption that bandwidth and resources are readily available when using various applications. While the evolving new wireless technologies offer enhanced bandwidth and throughput, there are key features of wireless networks that need to be considered before building wireless devices that use packet services.

A good starter reference is available at AT&T's Emerging Devices Organization web page, which provides an overview of the wireless network fundamentals for device design at http://www.att.com/edo/launch-your-device/information-center.jsp. The "Wireless Network Development Considerations" document provides an overview of the considerations.

7.1 Radio Network Design Considerations

- Wireless networks provide services where the bandwidth is constrained, especially radio resources which are based on the licenses for the spectrum in which AT&T operates. Radio resources are “shared” and therefore require efficient use.
- Wireless networks employ stringent **admission control mechanisms** to manage user’s access to various services. When a device decides to start an end to end packet application or resumes packet traffic after a break, the radio channel resources have to be allocated (which contends with other users) before it can transmit. This is a key difference where the wireless network allocates resources as required based on “admission control” mechanisms built in various nodes within the wireless network. Devices have to request radio resources (if they are not currently allocated), be approved, and then they can transmit.
- While the device may keep an IP address that it has been allocated for some time, the radio network resources are only allocated on an “as needed” basis. To that end, radio resource usage needs to be optimized when using wireless network for IP services. With various applications on the mobile device requiring communication with the server off the IP network (for application servers), it is important to design applications that do not:
  - Overburden the radio network with repeated, low throughput “keep alive” messages, i.e., keep alive messages to keep **PUSH** applications active
  - Allow applications to be designed that send sporadic packet data traffic with little or no flow control. When a packet is transmitted from a mobile to application server, each of these results in signaling and overhead to carry the IP packets. Therefore, efficiently designed applications will allow for a better user experience.
  - Behave the same way as they behaved in wired networks.
- Every transaction on the IP layer between the mobile and the application/host results in signaling on the wireless network to establish the radio resources to carry IP traffic. While the IP address is retained for a longer period of time, the radio channel resources are constantly setup and torn down. This impact needs to be understood and measures put in place to overcome excessive signaling impact when building applications on the device.

7.2 End to End Service Design Considerations

- Subscribers have to be authorized to use a wireless network for their IP services using their credentials provided in a SIM. This authorization is a key step before any IP based services can be offered. Besides this, there are other authentication and security measures (Ciphering) that are required as part of any service available to a user before the user can obtain or retransmit packet data even while an IP address may be present. As users roam into various network operators, users may obtain a different level of services based on their subscriptions.
- If devices are capable of voice and data simultaneously, then transitions from data only mode to data/voice mode and vice versa need to be considered carefully when building applications capable of running in the background that use voice and data.
  An example of this is when building streaming applications, consideration should be given to the behavior of the device when the user makes or receives a voice call. When applications use packet data, voice calls may or may not be present. This results in establishing connections to both circuit (voice) and packet data wireless components. This requires the device to consider how the packet data applications behave when voice calls are active.
- The device may be used across various generations of technology and radio conditions, so careful consideration needs be employed to handle network transitions and radio conditions. For example, devices may go through a 3G area and switch to 2G area (or 4G LTE technologies) as the subscriber moves around. This would result in varying user behavior that needs to be considered. A common example is in streaming applications, where many applications buffer enough data to offset any changes.
- Another key factor that needs to be considered while building applications is latency. Latency can occur for many reasons, including RF coverage, RF conditions, technology, and mobility. Applications that operate in wired environments need to consider latency when adding wireless access. For example, a gaming device with real-time user experience would need to consider adding mechanisms that mitigate or offset latency when users play games over wireless network.

- A key consideration is roaming as the device roams into various network operators, especially if the device is built as a global device. The performance of the packet data services is dependent on the network and operator services:
    - 2G capability
    - 3G capability
    - Subscribed services during roaming
    - Security restrictions in the visited network
    - Billing considerations, such as roaming charges
- Multi-technology access control is another factor that needs to be considered when building the device. The device may have WiFi, cellular and other forms of wireless access along with traditional access methodologies such as LAN (depending on the device). It is important to consider these items when building services especially where the user may be transitioning to multiple access methods or may have a choice of multiple access methods. An example of this is use of WiFi offloading with a WISPr client to offload the wireless network for data applications when available.

7.3 Device Considerations

- **Battery consumption** and **battery usage needs** should be carefully designed when building a wireless device. Devices that constantly run applications in the background that exchange data with servers will reduce battery life. Also, the radio network adjusts the power of the device to meet a desired quality of transmission which may result in higher battery usage. Standby and voice/data applications, and their effect on battery life, needs to be utilized to build efficient batteries for the device. This should also be tied with radio network and end-to-end design considerations – suboptimal design will adversely impact battery life in addition to inefficient utilization of network resources.
- **Display technology** and the resultant use of the display for various applications when users are actively using the device vs. non-use times needs to be considered. Providing user controls for display timeouts and also adjusting application behavior when a display screen times out is an important consideration.
- **Fast Dormancy** is a concept that applies to 3G technology that AT&T employs which, if incorrectly designed, could generate increased signaling traffic on the network and add latency to the user.

Fast Dormancy allows a device to quickly move from active state to an idle state. While there may be battery saving benefits, a well designed fast dormancy algorithm should consider applications that are active, display status and user action before initiating fast dormancy.

Fast Dormancy should only be used for PDP Context serving non-real-time background applications for which activity is not real time user interactive, closely spaced. Such applications include e-mail, visual voicemail, etc. Additional information is provided in the AT&T requirements document, 13340.

7.4 Summary

When a device developer designs a wireless network device for various services, consideration should be given to the user's device experience as the user accesses various services on the device, the type of access (packet vs. circuit) they receive, network and access technology that will impact performance, as well as expected user experience from an end to end perspective.

8 Cooperation with the Wireless Network

The wireless network is shared by all users of the network. Its capacity is limited by the available spectrum. To ensure optimal performance for all, each device needs to be friendly to the network and to its peer users.

8.1 Problem Statement

It has been observed (see discussion below) that some devices behave very "aggressively" in the wireless environment. The aggressive behavior wastes network bandwidth and resources. In some extreme cases, aggressive behavior can cause temporary network failures or prolong the recovery time of network from such failure. At the same time, aggressive behavior gives little if any benefit to the device. On the contrary, it shortens device battery life. Following are some examples of device aggressive behavior.

- Some devices try to resend registration/service requests with little or no delay after the request is rejected or ignored by network.
  There are various reasons for the reject or ignore such as temporary failures such as "network failure" or "network congestion".
  Some failures are permanent such as unregistered SIM, "user is not authorized for the service" and other states.
- Some devices check in with the application server too frequently. It might be OK in the wired network. It should NOT be done in the wireless network.
- An example would be a smartphone that pings an Internet time server every 10 minutes. It is not necessary. Even though it is not significant from a single device perspective, it will waste a lot of limited bandwidth when there are tens of thousands of devices doing similar things in AT&T's network.
- Recently a carrier network suffered temporary service degradation when an independent application developer released an instant messaging application that was designed to refresh its network connection with substantial frequency. This was reported in several newspapers/publications.
- Some devices behave very aggressively when the server is unreachable.
- A device will ping its server on power up. If the server is not available, the device will ping the server every 5 seconds continuously. When we have thousands of

such devices in AT&T's network doing the same thing, it is a denial of service attack.

- A device continuously tears down and re-establishes PDP context in the lab testing because it cannot reach its server.

8.2 Design Guidelines

The following are some design guidelines when building a device ensuring that it is being friendly to the wireless network:

- If the registration/service request fails, the device must act according to the failure cause, which is normally reported through AT command interface or software API. AT&T introduced a new proprietary AT command "AT $ARME" to improve the transparency of the failure cause. The details of the command can be found in AT&T's document 13340. Please check with chipset/module vendor on how to get access to the failure cause.
- In the case of temporary failures (If registration/service request fails because the network is congested or down), the device must use a back off algorithm to decide the time for the next attempt.
- In the case of permanent failures (If registration/service request fails because the user is not authorized for the service), the device must not use the service again until the authorization is obtained.
- The device must NOT check in with device/application server too frequently and must employ tactics to aggregate these queries based on the type of request. Frequent check ins with server might be acceptable in the wired network but it must be prevented in the wireless network.
- When the server is unreachable, the device must use a back-off algorithm to decide when to contact the server again.

8.3 Summary

To avoid aggressive behavior in the wireless network, it is important in the design phase to take into consideration the items discussed earlier. Some of behaviors that are considered normal behavior in the wired network are not acceptable in the wireless network. AT&T has a set of tests that the device has

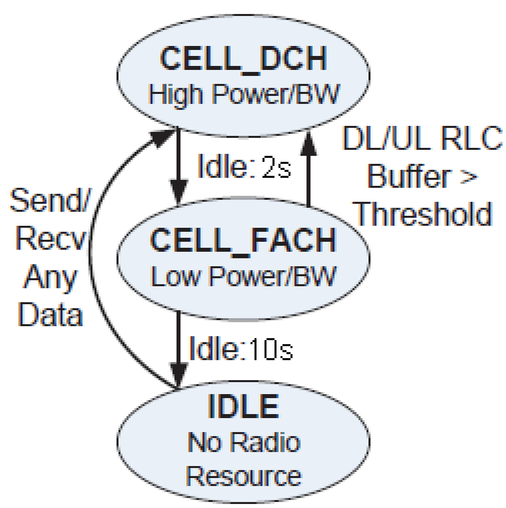
to pass in the device approval process to ensure the devices are friendly to the network.

9 Signaling Impact

9.1 Problem Statement

The raw processing power and bandwidth available to devices, coupled with the low cost of storage and silicon, allow for rich and elaborate implementations of always-connected cloud-based experiences. Everyday, new and exciting ways to connect users are created and delivered to AT&T customers. What is not well understood about these unique use cases are the costs associated to the network, customer billing, and device health.

The costs to the network affect all users on any given cell. Since a fixed set of radio signaling procedures is required for creating a data connection, the least efficient use would be to continuously set up a dedicated data channel only to pass little to no user traffic (i.e. a constant ping) as seen below.



Time	Direction	Protocol	Message	Source IP	Destination IP
3:57:43 PM	UE ----------> NETWORK	RRC	rrcConnectionRequest - Mobile Originated		
3:57:47 PM	UE <---------- NETWORK	RRC	radioBearerSetup		
3:57:47 PM	UE ----------> NETWORK	IP	Echo Message	192.168.2.12	192.168.2.13
3:57:47 PM	UE <---------- NETWORK	IP	Echo Reply Message	192.168.2.13	192.168.2.12
3:57:50 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: DCH to FACH		
3:57:56 PM	UE ----------> NETWORK	RRC	measurementReport		
3:57:56 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: FACH to DCH		
3:57:58 PM	UE ----------> NETWORK	IP	Echo Message	192.168.2.12	192.168.2.13
3:57:58 PM	UE <---------- NETWORK	IP	Echo Reply Message	192.168.2.13	192.168.2.12
3:58:00 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: DCH to FACH		
3:58:05 PM	UE ----------> NETWORK	RRC	measurementReport		
3:58:05 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: FACH to DCH		
3:58:06 PM	UE ----------> NETWORK	IP	Echo Message	192.168.2.12	192.168.2.13
3:58:06 PM	UE <---------- NETWORK	IP	Echo Reply Message	192.168.2.13	192.168.2.12
3:58:09 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: DCH to FACH		
3:58:13 PM	UE ----------> NETWORK	RRC	measurementReport		
3:58:13 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: FACH to DCH		
3:58:14 PM	UE ----------> NETWORK	IP	Echo Message	192.168.2.12	192.168.2.13
3:58:14 PM	UE <---------- NETWORK	IP	Echo Reply Message	192.168.2.13	192.168.2.12
3:58:17 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: DCH to FACH		
3:58:22 PM	UE ----------> NETWORK	RRC	measurementReport		
3:58:22 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: FACH to DCH		
3:58:23 PM	UE ----------> NETWORK	IP	Echo Message	192.168.2.12	192.168.2.13
3:58:23 PM	UE <---------- NETWORK	IP	Echo Reply Message	192.168.2.13	192.168.2.12
3:58:25 PM	UE <---------- NETWORK	RRC	radioBearerReconfiguration: DCH to FACH		
3:58:36 PM	UE <---------- NETWORK	RRC	rrcConnectionRelease: FACH to IDLE		

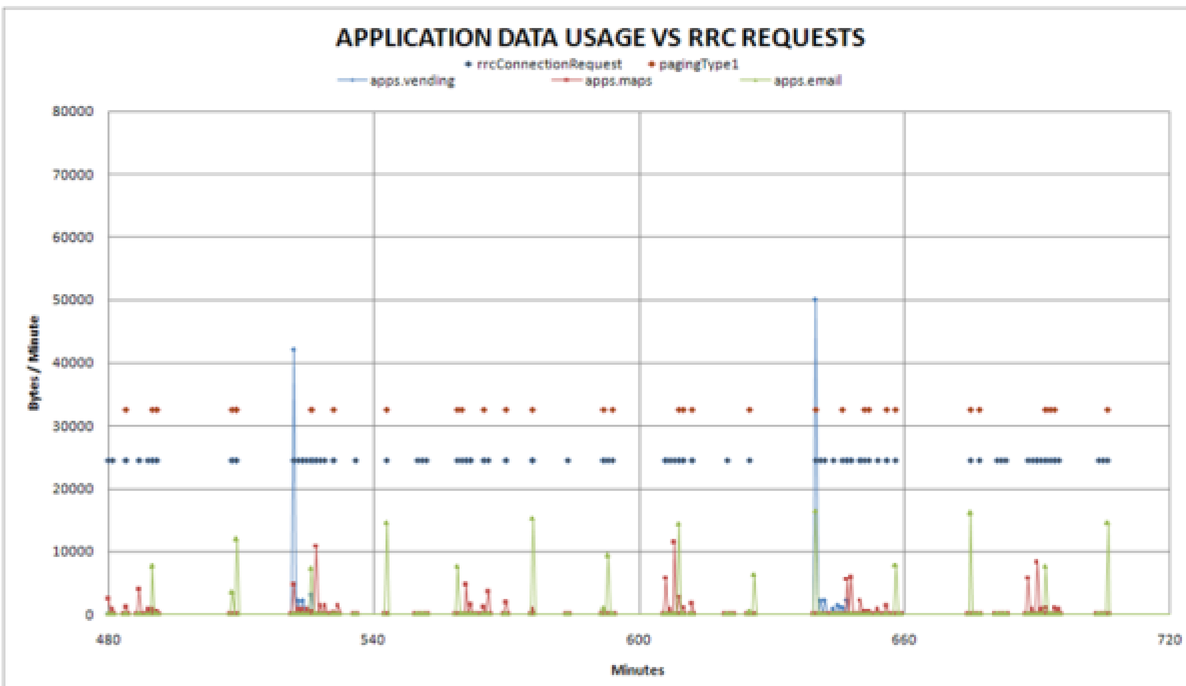
Given that an always-connected and constantly-updating UI is the most highly desired experience, we understand the need for significant updates when an application or component is brought to and left in the foreground. This may not be the same case for a component that resides several panels off to the side of a homescreen, or an application that is left to run in the background.

Another factor is customer billing, especially with capped data limits with tiered monthly pricing. If a component is frequently updating significant amounts of data, the summation of a months worth of unbeknownst activity could eat up the majority of a customer's data plan no matter how often they actually check the status of the component.

Another cost can be a device's perceived performance or health. Performing frequent and large data transfers will ultimately have an adverse affect on battery life and, possibly, voice call retainability for a user.

9.2 Design Guidelines for Signaling Impact

One of the unique characteristics of each device is the dormant and idle footprint. This footprint includes the data usage as well as radio signaling impact of a device, both out of the box and when provisioned with a single token that enables self updating portals like email / application market / IM / Location Awareness / Social Networks. Depending on how an operating system is designed to handle applications that run in the background, when an application or push service requests a dedicated data connection, a radio signaling procedure will be triggered by the device or the network respectively. Seen below is a scattered time series plot of application process / data throughput / and radio signaling connection event.



The above data was collected with no user activity and is the result of the device sitting in a completely dormant state but provisioned with always updating portals. As seen in the chart, pagingType1 shows push requests which are aligned with email-type activity. The other activities show no

corresponding page per connection request which would imply a device originated request.

Also seen are the groups of connections which have timers that may or may not have common factors, but look as if they are triggered in a sequential barrage. The time offset of each connection request often ties back to the time of the initial boot/application launch. The cost of this chart should be mapped as follows:

- To a network, these barrages of requests are a cost to processing load on the Network Core and RAN.
- To a device OEM, these barrages of request are a cost to battery life and heat as each request requires an active RF transmission as well as baseband processing.
- To a user, these barrages waste monthly data usage since these bytes of data transfer are occurring with no active user engagement.
- Often, an Operating System will allow for the tuning of background application to be either disabled or toggled for certain peak hours. These tweaks should be considered during the OEM design cycle and made easily accessible to an end user for flexibility in handling a device's dormant behavior.

9.3 Summary

In the design of a wirelessly backed application, how the wireless interface is utilized is often a result of how the application is designed to operate on the device. Applications should not be designed to be aggressive, because of the potential negative effects on the mobile network operator (MNO), customer's billing, user experience, as well as perceived device quality. Care in understanding the dormant application performance as well as the available settings within an operating system that can be toggled for data access are all things that should be investigated when launching a new application or device.

10 Regulatory Considerations

10.1 Problem Statement

This section provides a high-level overview of regulatory considerations when designing a wireless device. It is crucial to take them into consideration during the early planning phase of the device architecture. Please note that regulatory and legal requirements are constantly changing, so it is often advisable to consult an expert on these issues.

10.2 Design Guidelines for Regulatory Considerations

Make sure these guidelines are considered during development.

- **AGPS**
  If a device in any form can make a voice call, the device must support the 3GPP defined control plane AGPS for E911 calls. In addition to control plane AGPS, SUPL (secure user plane AGPS) is required for all voice capable 3G devices. AGPS receive sensitivity should be equal or better than -140 dBm using coarse timing assistance and linear polarization. The antenna design need be optimized for upper hemisphere radiation and system interference should be minimized at GPS frequency for good sensitivity.
- **IEEE 1725/1625**
  The **IEEE 1725** standard was developed for rechargeable lithium ion and lithium polymer batteries used in wireless devices. The standard establishes criteria for design analysis quality and reliability. If a wireless device is Network Optimized or Stocked, its battery needs be IEEE 1725 Compliant and CTIA registration must be completed.
  IEEE 1625 was developed for cell, battery pack, and system management leading to design approaches for mobile computing devices, such as notebook computers. The standard focuses on design approaches for the reliable operation of mobile computing devices and similar rechargeable battery-operated systems with multiple cells in series or series and parallel. CTIA certification with IEEE 1625 must be completed, if applicable.

- **HAC**
  Handsets are required to be tested for HAC. HAC testing involves the measuring the magnetic and electric fields produced by a phone to ensure it does not interfere with the sound quality of a hearing aid. Handsets must be designed with consideration of HAC and optimum HAC measurements should be executed as part of product development.

10.3 Summary

Please follow the recommendations provided to meet the regulatory requirements, and for additional information please refer to *AT&T Device Requirements* AT&T Document Number 13340 for a list of requirements.

11 Non-Volatile Memory Configuration

11.1 Problem Statement

Non Volatile Memory (NVM) settings have significant impact on device behavior. A device might not behave as designed if NVM settings are incorrect. As devices go through lab and field testing, many identified failures are due to wrong NVM settings prescribed even though the firmware version is correct. This creates delays to the device certification process and wasted test effort which can be easily avoided by considering the guidelines.

11.2 Design Guidelines for Non-Volatile Memory Configuration

AT&T is working with chipset, module and device vendors to have an end to end process to track the NVM settings. When a chipset or module is approved by AT&T, NVM settings will be saved along with the firmware version for future reference.

Device developers must carefully review the NVM setting before lab testing. It is important that the device developer first identify reference settings provided by its chipset/module vendor. The device setting should be compared with the reference to identify any differences. The explanation for differences must be documented and sent to the AT&T VC for review. AT&T is requesting chipset vendors to provide a tool to compare NVM settings. Device specific settings (for example, RF calibration data) will not be compared.

Device developers must make every effort to prevent changing NVM setting during the approval process as this will delay the device certification.

11.3 Summary

NVM has to be set correctly in order for the device to work properly. It must be carefully reviewed and tracked during the device approval process.

12 End Goal: Optimized Wireless Device – Network Ready Certification from AT&T

Before a wireless device is used on AT&T's network, the device needs to be certified for use on AT&T's network. In order to prepare the devices with wireless access, the device has to be designed with various key factors in mind which have been discussed in the sections above. The primary goal of this document is to provide guidelines. After the device has been designed, certification with AT&T is required, the benefits of which are discussed here.

When delivering solutions to AT&T customers, quality of service is our top priority. AT&T expects the same from device manufacturers. In order to help ensure that the solution chosen by our customers performs as required, AT&T has developed these guidelines and testing criteria to verify best-in-class devices.

The goals of AT&T Network Ready testing are to validate the following:

- The device does not perform erratically
- The device supports basic functions as intended
- The AT&T network will not be adversely affected by the presence of the device on the network
- The device meets the minimum RF performance requirements to operate on AT&T's network
- The device supports the necessary functionality to operate in a spectrally efficient manner on AT&T's network

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