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White Paper

Why Test GPRS?

GSM Mobile operators across the globe are rolling out new GPRS (General Packet Radio Service) networks. These provide advanced capabilities for users including always-on connection for e-mail and web surfing. As with all complex technologies, operating problems can arise and resolving them between phone malfunction, user training or network problems requires sophisticated, yet easy to use test solutions. For example, problems for users can occur if the phone fails to maintain output power during multiple bursts or if the sensitivity varies across the different time slots. These can disrupt performance and result in unhappy customers who are then tempted to switch network or phone.

Willtek have been at the forefront of mobile phone testing for over 40 years and this White Paper explains briefly the background to GPRS, the areas users may experience problems and how these can be tested and identified. An Appendix provides more detail of receiver and transmitter tests.

What is GPRS?

The General Packet Radio Service is a new protocol based on the GSM RF layer. It provides better spectrum (channel) efficiency for downloading bursty traffic such as www surfing and e-mail rather than circuit switched techniques. The physical resource (i.e. a time slot on a frequency channel) is shared by several mobile phones. Data packets are transmitted in blocks of data where each block may be used by a different mobile phone. It provides "bandwidth-on-demand" for users with an always-on connection. Multislot transmission and reception may be used to increase the user data rate. GPRS adapts to the transfer rate demanded, so the idle-time can be used by other customers hence benefiting from the nature of "packet based" IP (Internet Protocol) traffic. Channels are no longer assigned in both directions or for one mobile exclusively for the duration of an Internet session so that access in one direction does not necessarily mean that the other direction is also used by the same mobile. Customers can also be billed by the amount of data transferred rather than by the time spent online.

GPRS provides resources on demand, allowing for instantaneous network access and release. The physical resource - a frequency channel with an allocated time slot - may be shared by several GPRS users. Collision detection (familiar in Local Area Network technology) in the uplink is performed by the network: packet access is administered by the base station. As there is only one base station within each cell transmitting in the downlink, collision detection is not required in this direction.

In addition to channel sharing, GPRS allows the use of multiple timeslots to speed up the data transfer; this is an option for GPRS but is not required by default. If multislot operation is applied, the time slots use the same hopping sequence so that the mobile phone only needs to change the channel number once per frame. GPRS also introduces new logical channels called packet data channels (PDCH) that use 52-frame multiframe specifically introduced for the new service.

How fast is the data rate?

The network allows choice of 4 channel codec algorithms (Coding Schemes) to optimise either reception or data throughput. With different coding schemes and multislot operation, a large number of different data transfer rates can be provided.

Coding scheme	Max. data rate on one time slot	Max. data rate on two slots	Max. data rate on eight slots
CS-1	8.0 kbps	16.0 kbps	64 kbps
CS-2	12.0 kbps	24.0 kbps	96 kbps
CS-3	14.4 kbps	28.8 kbps	115.2 kbps
CS-4	20.0 kbps	40.0 kbps	160 kbps

figure 1 Coding schemes

Whilst many GPRS marketing campaigns quote a maximum data rate of 171 kbps, the achievable data rate experienced by users realistically depends on several factors, and understanding this can help explain the problem of "slow download speed".

Number of available time slots
It is very unlikely that a network will assign all eight time slots of a carrier to one mobile. Depending on network capacity and number of active users in a cell, the number of time slots may vary typically from 1 to 4.

Channel interference and coding scheme:
If the network selects coding scheme 4 (CS-4) and if the level of channel interference is low, the data rate is high. If interference increases to a high level, then the data rate perceived by the user may go down to zero because there are so many bit errors that the contents are lost. In this case, the base station selects a different coding scheme, for example CS-1. This coding scheme provides a high level of protection against channel interference but also a low data rate - the user data are effectively sent twice to increase the likelihood that the receiver gets the contents. Many networks are not yet equipped to transfer data at higher speeds, so they restrict the data transfer to CS-1 and CS-2, which means data rates of 8 or 12 kbps per channel.

Number of phones sharing the same time slots:
Multiple users may share the same channel; the more traffic these users demand at the same time, the lower the data rate will be for all users.

Multislot class of the phone:
For each type of mobile phone, the multislot class defines the capabilities. Most phones today are of class 10 or below. (Multislot class ranges from 1, with 1 uplink and 1 downlink slot available at the same time, to 29 with 8 downlink and 8 uplink slots. Class 10 provides up to 4 downlink and 2 uplink slots.

Direction of data traffic:
Most Internet users download a lot of data, but do not upload as much. Given that the channel capacity is the same in both directions, this means that there may be higher capacity available to an individual user in the uplink when the network is congested. The multislot class of the phone, however, may restrict the uplink data rate since most mobiles provide more capacity in the downlink than in the uplink.

Protocol overhead:
The data rate quoted for the lowest protocol layer is not the one perceived by the user. The theoretical maximum speed of 171 kbp refers to the lowest protocol layer, the Medium Access Control (MAC) layer. The added overhead data from the higher GPRS protocol layers reduces the rate (160 kbps in the example), and additional protocols (such as TCP/IP) may lead to further decreases.

What kinds of problems arise?

Introducing any new technology can create problems. Mobile phones may still be at early versions of firmware and feature set, users may be inexperienced in operation and GPRS network coverage is by no means universal so users may experience problems as they move around. The GPRS specification places considerable demands upon the technology, particularly at high power levels and high data rates when time slots are shared and combined. Deciding where the problems lie and resolving them requires sophisticated tests to be performed and the results checked against specifications so accuracy is essential. The time taken to make measurements is critical in many situations, so speed is important as well as test technique.

Re-use of the GSM RF layer could mean that when testing the RF behaviour of the mobile phone, no additional tests are required. However the picture is more complicated. GPRS channels are unidirectional so that if the mobile needs a two-way connection, the packet data channels may be on different time slots (for example a downlink channel on slot 2 and an uplink channel on slot 3).

And for the assignment of a new uplink block, the phone may have to listen to the signalling on the down-link channel of the same slot (slot 3 in the example). In essence, this means that although the user experiences single-slot transmission only, the mobile must in fact receive in multiple slots. The challenge is even higher when the mobile transmits or receives data on multiple slots!

Multislot transmission implies that the phone must keep the power level constant over each time slot. This poses new challenges to both the phone and the battery, in particular at high output power levels. If the supply voltage from the battery drops towards the end of the multislot transmission, this can result in a failure to meet the burst template for power and frequency. It can also produce problems from an increased frequency error since internal oscillators have voltage-controlled frequency adjustments and these may be affected.

With uplink power control, the mobile must be able to switch its output power to different levels between adjacent time slots, within the allowable limits of both the power/time template and the switching spectrum, and this needs to be confirmed by accurate measurements.

The multislot receiver and its automatic gain control must be able to properly receive the incoming signal on multiple time slots at varying levels, for example when the base station performs downlink power control from slot to slot.

The loop-back method for error rate measurements known from standard GSM may not be practicable as most mobile phones do not support multiple slots in uplink and downlink at the same time. For GPRS, Block Error Rate (BLER) measurements have been defined as a useful method to evaluate the receiver quality on packet data channels.

The new standard poses new challenges for testing mobile phones in areas such as multislot transmission and reception. Willtek make a range of mobile phone testers with the 4200S and 4400 series. The 4261 GPRS Go/NoGo Option for the 4202S tester is aimed at meeting basic service needs; the 4262 GPRS measurement option for the 4202S provides more measurement capabilities. The 4403 and 4405 provide fast, accurate high performance measurements in major service centres and for production testing. The capability for accurate multi-slot power time template tests is illustrated with the screen shot in figure 3 from the 4405.

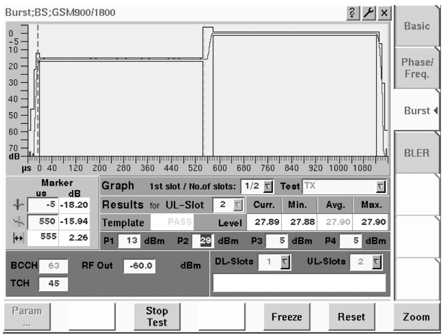

figure 2 Multislot Power Time measurements

How are GPRS phones set up for testing ?

Making standard GSM receiver and transmitter phone tests is well known, but with the wide variety of new GPRS phones on the market, some guidance is helpful on getting started. In fact for many first time users who experience problems, these procedures are useful reminders if the customer has difficulties in getting GRPRS service such as Internet access.
Listed below are some hints to test set ups.

Nokia (6310i, 8310)
To start GPRS tests, Nokia phones must be switched to GPRS mode (just as you would to request content from the Internet)
Menu - Services (select) - Settings (select) - Edit active service settings (select) - GPRS connection (select) - Always online (select) - OK

Siemens (S45, ME45)
Siemens phones must be set up to request data from the Internet; the easiest way is to select the pre-defined homepage:
Menu - Surf & Fun (select) - Internet (select) - Homepage. The data bearer might need to be set to GPRS: Menu - Setup - Connectivity - GPRS (select). Siemens also offers a software download from its Internet pages (http://www.my-siemens.com) to upgrade older S45/ME45 to GPRS multislot class 8.

Ericsson (T68)
The T68 can be brought into a state where it listens to GPRS paging. From the on-screen menu, select the items in the following sequence:
Menu - Connect (enter) - Data comm. (enter) - Pref.service (enter) - GPRS and GSM (enter)

Ericsson (T39m)
The T39m works in a similar way to other phones to select GPRS service:
Menu - Settings (enter) - Data comm. (enter) - Pref.service (enter) - GPRS and GSM (enter)

Motorola (T260)
The Timeport 260 does not support the GPRS Test Mode Command, so that transmitter and BLER-USF measurements in GPRS mode are not supported. You can, however, start the BLER-BCS tests. For these receiver measurements, the Timeport 260 needs not be switched to a dedicated mode; it always accepts the GPRS paging.

More Details of GPRS Measurements

Test Background

Whilst virtually all GPRS phones are designed for multislot receive capability, they may or may not be able to transmit on multiple time slots. For the mobile phone equipped with single slot transmitter and multislot receiver, the normal GSM transmitter tests apply. For the receiver quality it is essential to check the sensitivity on consecutive bursts; individual ETSI requirements exist for the different coding schemes. On GPRS channels, different limits apply and it is not always trivial to correlate them with the GSM receiver tests.

Receiver sensitivity is tested using bit or block error rate measurements; for a reasonable certainty of the results, these measurements have to be taken over an extended period of time. Tests on multiple time slots can be advantageous because they can shorten the time for testing a given number of samples. The most suitable method for testing the receiver (hardware) quality is the BLER-BCS test with CS-4. Other coding schemes add redundancy to the data and hence the quality of the channel decoder (software) impacts the results. The mobile phone must be able to cope with varying receive power levels. To check the automatic gain control AGC in the receiver, reception of multiple slots with varying power can be a challenge. A comprehensive radio test set such as Willtek 4400 series allows the output power of the instrument to be individually set up per time slot for this purpose. A phone with multislot receiver and transmitter faces the same receiver challenges as above.

On the transmitter side, the phase and frequency errors and the output power are of interest, in particular the power level versus time. In the last of several consecutive bursts, the supply voltage may drop and affect the power/time template as well as the peak phase error.

With modern high-end radio test sets, GSM measurements on the transmitter and receiver can be taken in parallel. This principle also applies to BLER-USF measurements where the mobile must transmit and receive at the same time. As the test that should be performed in a manufacturing environment differs a lot between different HW architectures, no general statements can be made. However, some measurements that are of particular importance are the phase/frequency and output power performance. For multislot transmitter (and also receiver) measurements, the BLER-USF test is suitable. Downlink power control is not checked in the conformance test specification. Nevertheless, the ability to cope with downlink power levels varying from slot to slot can be a substantial differentiator in the market; it can be tested easily with the existing BLER and BER methods by simply applying different downlink power levels between the time slots.

Receiver tests

Circuit switched receiver measurements are based on the fact that channels are bi-directional or even symmetrical; received bits are looped back to the tester which counts the bits received that are wrong. GPRS channels are unidirectional; although an independent channel could be set up in the other direction, a multislot phone may not support their maximum number of downlink slots in the uplink and even at the same time. The two standard methods are therefore based on standard mechanisms in the lower layer GPRS protocol: acknowledgement of received blocks and uplink addressing.

BLER-BCS Block Error Rate based on the Block Check Sequence
On the packet data traffic channel PDTCH, the receiving side acknowledges to the transmitting side if the data blocks have been received properly. If the channel decoder cannot correct bit errors, the whole block is discarded and a packet negative acknowledgement (NACK) is sent, indicating which blocks have been received in error. Even if a block is missing completely, this can be detected by means of the block sequence number in the RLC header. The NACK message allows the transmitting side to only re-transmit those blocks which are required. ACK/NACK messages do not require their own TBF in the opposite direction but are transmitted on the PACCH which is the only bi-directional packet data channel. For the purpose of receiver testing, this feature is used to count block reception errors, typically at low power levels or under fading and/or interference conditions. The measurement is called BLER-BCS (block error rate based on the block check sequence) because it is the check bits which help the channel decoder determine wrong from right data blocks. As the measurement is based on standard GPRS principles, it is usually operational in the mobile phone without any additional code for test purposes. All the phone needs to support, is the establishment of a PDTCH without a higher layer connection (such as a PDP context and user data transfer).

This test method is well suited to test the mobile receiver quality on one or multiple time slots, does not require additional capabilities from the mobile phone, uses a downlink TBF only and can therefore be performed independent of the number of slots simultaneously supported in the uplink.

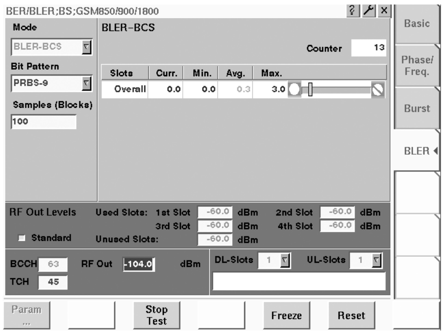

figure 3

BLER-USF Block Error Rate based on the Uplink State Flag
In normal operation of an uplink TBF, a packet data channel can be allocated either dynamically or fixed to transfer RLC data block transfers. In dynamic allocation, the mobile phone has to observe the USF sent by the base station in each MAC block on the same time slot. When the mobile receives its USF in the downlink, it has to transmit the next uplink block, no matter whether it has data to send or not.

This feature is used for receiver measurements by allocating an uplink TBF and randomly setting the mobile's USF in the MAC header. When receiving its USF in the MAC header, the mobile phone must send data in the next block. Depending on the mobile's capabilities, the data must either be retrieved from the downlink and looped back, or generated inside the mobile by a pseudorandom bit generator.

Each time the mobile phone does not transmit a block although it has been addressed, this is counted as a block error because it can be assumed that the mobile did not receive the USF successfully. The measurement is referred to as the BLER-USF test (block error rate based on the uplink state flag).

Two cases can be distinguished: the USF can be sent in downlink blocks which are channel encoded with either CS-1 or any other of the coding schemes. In case of CS-2 through CS-4, the USF is coded exactly the same way, so the BLER-USF results should not differ.

The BLER-USF measurement is based on an uplink TBF, which is usually requested by the mobile phone. The RLC/MAC layer in the phone only originates a TBF if a higher layer needs to send data over the air interface (for example if the user requests data to be sent). For the purpose of RF testing, one would not want to use an application and all the additional signalling overhead, so a GPRS test mode "A" has been defined (GSM 04.14). In this test mode, the tester rather than the application initiates the uplink TBF request from the mobile. The tester sends the GPRS Test Mode Command to the mobile phone, indicating on which time slot the phone shall request the uplink TBF. Note that although the phone initially only requests the uplink TBF on one slot, the tester may assign multiple uplink time slots.

For type approval, BLER-USF measurements are specified over 20,000 samples (blocks) under static propagation and 60,000 samples under dynamic propagation conditions depending on the coding scheme and frequency range (GSM 850, 900, 1800 and 1900)

This test method is well suited to test both the mobile receiver and transmitter quality at the same time because it uses an uplink rather than a downlink connection. It uses the GPRS Test Mode, which is a mandatory addition to the standard protocol.

While it has been said that BER is not available by default, it is also true that the block error rate measurements are very time consuming. A BLER sample is one block of data, that means spread over four TDMA frames. Consequently, 10,000 BLER samples measured on a single-slot packet data channel take at least 200 seconds which is quite a long time in manufacturing and service, compared to less than a seconds for a standard BER measurement in plain GSM.

Although in practise the sample size in manufacturing and service is much lower than 10,000, an optional method has been defined to ease GPRS testing for these purposes. It is useful for testing bi-directional multislot links, for example two time slots in each direction (this is not supported by multislot classes 1 through 4 and 8); it can, however, prove useful also for faster GPRS single-slot receiver and multislot transmitter testing.

In this mode (Test Mode "B"), both a downlink and an uplink TBF are set up. The phone loops back the data received in the downlink, block by block. Blocks present in the uplink only are filled with data from the last downlink block. The GPRS BER test can lead to a sample rate much improved over the BLER tests. With CS-4, 10,000 samples take roughly 550 milliseconds on one time slot or 300 milliseconds on two slots. With CS-1, the same number of samples takes about 1.3 seconds on one slot.

Similar to the C loop in GSM, the BER measurement is a voluntary measurement to improve the processes in manufacturing and service, with no BER test limits defined in the ETSI standard. Since all present designs use a maximum sum of five time slots, the loop back can be performed on one or two slots only.

If implemented in both the tester and the mobile phone, the BER measurement is a powerful tool to test the GPRS transmitter and receiver in multislot mode within very short time.

Transmitter tests

Professional users also need high-speed data in the uplink, and this requires mobile phones capable of transmitting on multiple time slots per TDMA frame. This poses new challenges on mobile phone design and the battery. The worst case occurs when the phone has to transmit at maximum power level in consecutive bursts, leaving battery and capacitors in the phone less time to recover.

Parameters to be tested are the frequency error, phase error, peak power level and power versus time. In the latter test, the power level is examined over all the time slots including the guard period between active slots. The other parameters are examined slot by slot using the conventional test methods.

In the power versus time test, a modified power/time template is used. This consists of several sections:

- For each time slot, the active part of the burst is examined separately. The average power over the active part is determined and the standard template (±1 dB limit) is drawn around the average.
- The standard template applies to the rising edge before the first active time slot as well as to the falling edge after the last active time slot.
- Between the active parts, the maximum allowable power level depends on the levels in the active parts: The output power between consecutive active time slots shall not exceed the level allowed for the useful part of the first time slot, or the level allowed for the useful part of the second time slot plus 3 dB, whichever is the highest. (see figure , which is a Zoom-In on the transition between two bursts)

Another case that needs to be examined is proper power level setting in the active parts of adjacent slots. This is also tested in standard ETSI tests, where the mobile phone is required to transmit the first time slot with maximum power level, the second with minimum level and the others with maximum level again. The same parameters as above are tested.

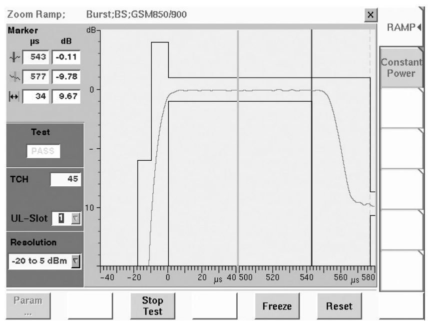

figure 4

Glossary

BER	Bit Error Rate
BLER	Block Error Rate
BLER-BCS	Block Error Rate based on the Block Check Sequence
BLER-USF	Block Error Rate based on the Uplink State Flag
CS	Coding Scheme
ETSI	European Telecommunications Standards Institute
GSM	Global System for Mobile communication
GPRS	General Packet Radio Service
IP	Internet Protocol
kbps	kilobits per second
MAC	Medium Access Control
NACK	Packet negative acknowledgement
PACCH	Packet Associated Control Channel
PDCH	Packet Data Channels
PDP	Packet Data Protocol
PDTCH	Packet Data Traffic Channel
RLC	Radio Link Control
TBF	Temporary Block Flow
TCP/IP	Transmission Control Protocol / Internet Protocol
TDMA	Time Division Multiple Access

Further Reading

Willtek Seminar Booklet: An Introduction to GPRS
Willtek Data Sheet 4400 series
Willtek Data Sheet 4200 series
ETSI Specifications

Note: Specifications, terms and conditions are subject to change without prior notice.

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