General Packet Radio System (GPRS) Testing: Why and How?

Application Note 1384

Agilent Technologies

Introduction

Since GPRS is intended to be used for data transfer, quality and device reliability are important factors for maximizing the system network’s overall performance. Given that networks have limited capacity, marginal RF performance effects the data rate of the entire system. Higher quality GPRS devices allow network resources to be used more effectively, improve network efficiency, and facilitate faster data rates.

This document is intended to highlight conflicts of interest surrounding GPRS test in the mobile phone industry and give an insight into some of the technical difficulties encountered in the transition from GSM to GPRS mobile phone production. Rather than explaining GPRS or GSM technology, this paper outlines issues that make GPRS testing during device manufacturing an important procedure, explains why GPRS testing is necessary, and shows how testing can be accomplished in order to produce good, reliable GPRS devices.

Table of contents

		page
1	Why test GPRS	4
1.1	NOP/NEM conflicts of interest	4
1.2	Progression from GSM to GPRS and the related difficulties	4
1.2.1	Timing of up/down link bursts	5
1.2.2	Receiving adjacent bursts at different power levels	6
1.2.3	Transmitting adjacent bursts at different power levels	7
1.2.4	Output RF Spectrum (ORFS) due to switching	7
1.3	GPRS without test	8
2	Methods of testing GPRS	9
2.1	Test modes	9
2.1.1	BLER mode	9
2.1.1.1	Using BLER mode to assess receiver sensitivity	10
2.1.1.2	What do the specifications state	11
2.1.2	ETSI test modes	12
2.1.2.1	ETSI test mode A	12
2.1.2.2	ETSI test mode B	13
2.1.2.3	BER testing	13
2.1.3	Manufacturers test mode	14
2.2	Why use a protocol based test mode	15
3	Conclusion	15

1 Why test GPRS

Data transmission for the mobile station (MS) is heralded as the next big market for the communications industry. The deployment of GPRS technology is viewed as a key stepping stone towards migration to 3G and is fueling a headlong rush to get new products out.

The manufacturers' race to be one of the first to offer a cost effective GPRS handset, has given rise to problems. GPRS is a complex system and devices are much more complicated than their predecessors were, which has created difficulties in providing GPRS terminals that operate reliably on networks. The problem has been made worse by the lack of requirement for third-party type approval for GPRS.

As this paper discusses, understanding and implementing test requirements and methods for testing of GPRS terminals is imperative for manufacturing success.

1.1 NOPs and NEMs conflict of interest

Network operators (NOPs) are facing considerable challenges as the MS market matures. Issues of increased costs (3G licenses) and lower revenues mean that a new revenue stream and greater utilization of existing bandwidth are becoming an urgent requirement. GPRS could offer this opportunity provided the content is useful and the technology reliable.

Network equipment manufacturers (NEMs) are also facing an increasingly challenging market place and have cost considerations of their own. With the price of MS falling, NEMs must take measures to reduce costs and maintain margins. One potential way to do this is to minimize test in the manufacturing process. The resulting increase in throughput and reduction in outlay for manufacturing equipment are seen as big incentives. However, this removal of test is contrary to the interests of the NOPs.

The performance of a GPRS network is substantially degraded by MSs with poor RF performance. Unlike GSM telephony, when a block of corrupted data arrives at the GPRS handset, it will request a retransmission. If this happens regularly, the user will experience a poor data rate and the network will become ‘tied up’ with retransmission of data, slowing the data rate for all other users in the cell. Also, the user's battery life will be reduced by the extra transmission of data. As GPRS devices can be multiple uplink capable, battery life is very important.

Corruption of data can happen for many reasons. An obvious cause could be a poor receiver in the handset failing to correctly capture each burst. Other problems could be caused by poor transmitters in the MS failing to produce accurate bursts or creating interference for other users. The reasons why these problems are more likely in GPRS than in GSM are discussed later in this document.

Whatever the anticipated problem, NOPs will have a great interest in ensuring that all the MSs they use have been adequately tested to verify optimum RF performance. This requirement seems to contradict current trends by NEMs to minimize GPRS test.

1.2 Progression from GSM to GPRS and the related difficulties

One industry view is that, as an extension of GSM, GPRS can be adequately tested using existing GSM test methods. More clearly stated, ‘it should be possible to confirm the GPRS performance of a handset by testing only its GSM performance’. This view stems from an early consensus that to achieve GPRS functionality would require only software changes to a GSM MS. However, some manufacturers are now finding that over 75% of the design of the device required modification to achieve GPRS functionality.

Some of the main difficulties encountered are described in sections 1.2.1 through 1.2.4.

1.2.1 Timing of up/down link bursts

With traditional GSM, the timing of the uplink and downlink channels is offset by three timeslots (see figure 1). This means that if the MS receives on downlink timeslot 0, the MS does not transmit until the downlink equivalent of timeslot 3. The result is that a GSM MS always has two timeslots to switch between RX and TX.

GPRS does not afford the MS this luxury, often giving a maximum switching time between uplink and downlink of one timeslot rather than two. This places a much greater strain on the MS's ability to re-tune and lock on the different frequencies (it puts demand on the local oscillator (LO) and its phase lock loop (PLL) performance). It also leaves a shorter time for the MS to retune to 'listen' to surrounding cells for their BCH.

To cope with the added strain, GPRS MSs must have a more agile LO to retune in such short time periods. Verifying the increased agility of the MS receiver is an important test for GPRS. When the LO/PLL fails to settle quickly enough, increased frequency error occurs. Significant phase error at the start of the burst can also be attributed to slow settling of the LO/PLL. As with other problems, these errors will result in corruption of data.

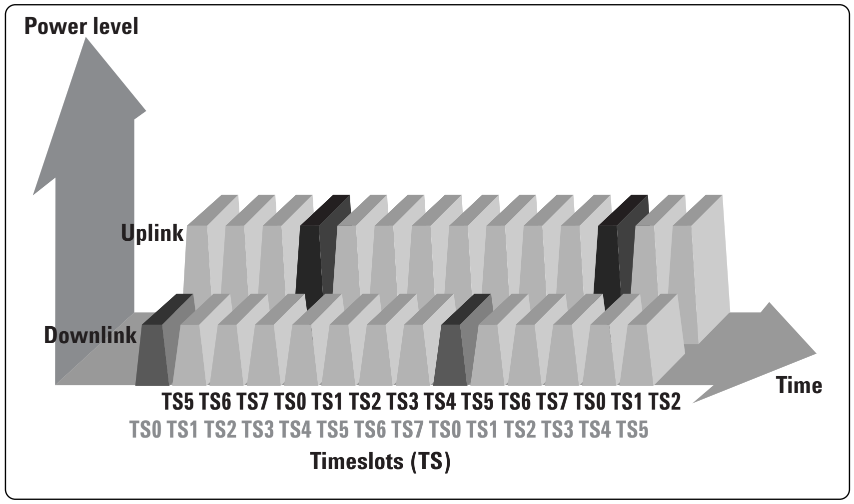

Figure 1a. Burst offset arrangement in GSM

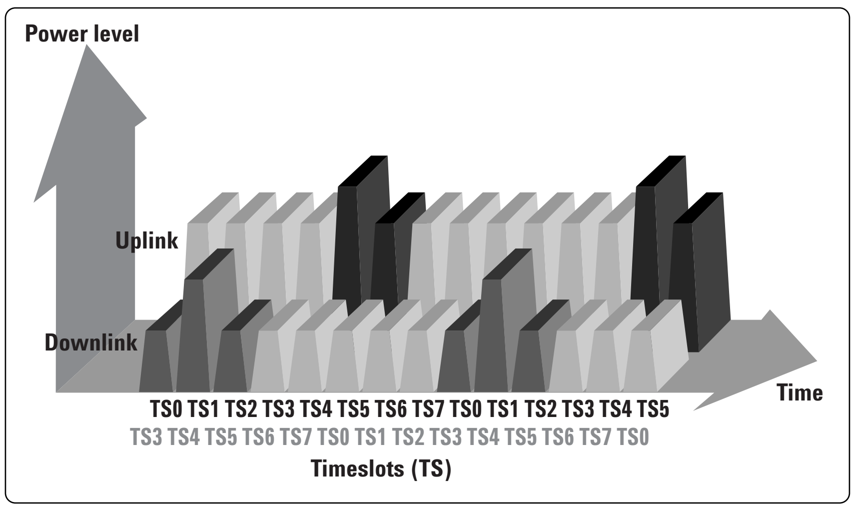

Figure 1b: Burst offset arrangement in GPRS

1.2.2 Receiving adjacent bursts at different power levels

In standard single slot GSM, each frame contains only one burst of data per mobile on the downlink. Changes in the power level of this burst are normally communicated to the MS once every 26 frames on the Slow Associated Control Channel (SACCH) or on the Fast Associated Control Channel (FACCH) (by stealing speech frames). With GPRS, the MS can receive data on multiple time slots in the same frame, the power of each burst differing by up to 10 dB from the previous. To cope with these adjacent transitions, the gain control of the amplifier in the RX stage of the MS must be able to adjust and settle much faster than was required in GSM. Specifically, rather than managing the transition over one frame period, the MS must now achieve the transition within the ramping periods of the adjacent timeslots. This is only 34 µs as opposed to the 4 ms afforded in GSM (see figure 2).

If the amplifier cannot adjust fast enough then corruption of data is likely to occur. A commonly observed problem is where the amplifier fails to adjust to a higher gain rapidly enough. If two bursts are transmitted with the second at a much lower power than the first, the receiver can become saturated, destroying the data and prompting a retransmission. This situation results in increased network traffic and lower network efficiency. Problems have also been seen on the opposite transition, with the first downlink timeslot set to a lower power level than the second. This issue is due to the slew rate of the automatic gain controller (AGC) being too slow.

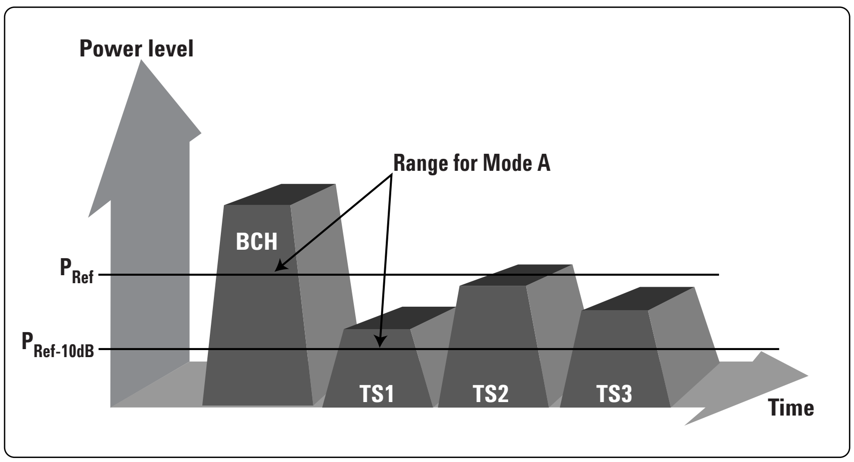

Figure 2. Period between bursts is only 34 µs

1.2.3 Transmitting adjacent bursts at different power levels

The existing ETSI defined PVT mask for GSM has been modified to allow for multiple contiguous uplink timeslots at different power levels. Similar to the case of the adjacent RX, this places additional strain on the TX stages. In the standard GSM PVT mask, the MS only has to cope with the ramp up, overshoot, useful part, and ramp down characteristics of a single burst. The multiple adjacent uplink bursts possible in GPRS mean a MS has to transmit for much longer periods while also contending with power level transitions between bursts.

These uplink bursts can differ in power by up to 30 dB. Achieving sufficient burst level accuracy on these uplink transitions can prove very difficult. The resulting performance varies considerably depending on the variation in burst power level, the nature of the transition (Hi/Lo or Lo/Hi) and the method of burst transition that is adopted (see section **1.2.4 Output RF Spectrum due to switching**). The extent to which the effects are seen can be markedly different from MS to MS even with the same model.

As the GPRS transmitter may now be capable of transmitting on more than one timeslot it is also necessary to consider the thermal implications that might impact the TX performance over long TX sequences.

1.2.4 Output RF Spectrum due to switching

Output RF Spectrum (ORFS) due to switching measures the spread in spectral RF energy due to GSM/GPRS burst ramping. The results of this test are likely to be quite different for a multi-uplink GPRS MS compared to a GSM MS. In general, if the transmitter ramps too quickly, unwanted spectral energy spread will occur in the transmission. By spreading into other frequency channels, this effects the quality of service experienced by other users in the cell, thus increasing their TX power (reducing battery life) and increasing overall interference. If the MS ramps up too slowly, ORFS problems are avoided but you might see bit errors at the beginning of bursts or the burst will be outside of the specifications for power versus time. Also, if the MS is ramping much too slowly this interferes with users in adjacent timeslots.

The ORFS due to switching is likely to be quite different for a multi-uplink GPRS MS than for a GSM MS. This is because of the difference in the transition characteristics for adjacent bursts compared to a single burst. This transition must be within the PVT mask for the “guard period” between bursts.

A large consideration is whether the transition is achieved by using two normal GSM bursts, accepting whatever transients are produced between the normal ramp down/ramp up transition, or by blurring the transition and creating one double burst. Neither method has been specified in the standards so manufacturers must decide on one method and then ensure that it does not create an ORFS result that falls outside the defined frequency mask.

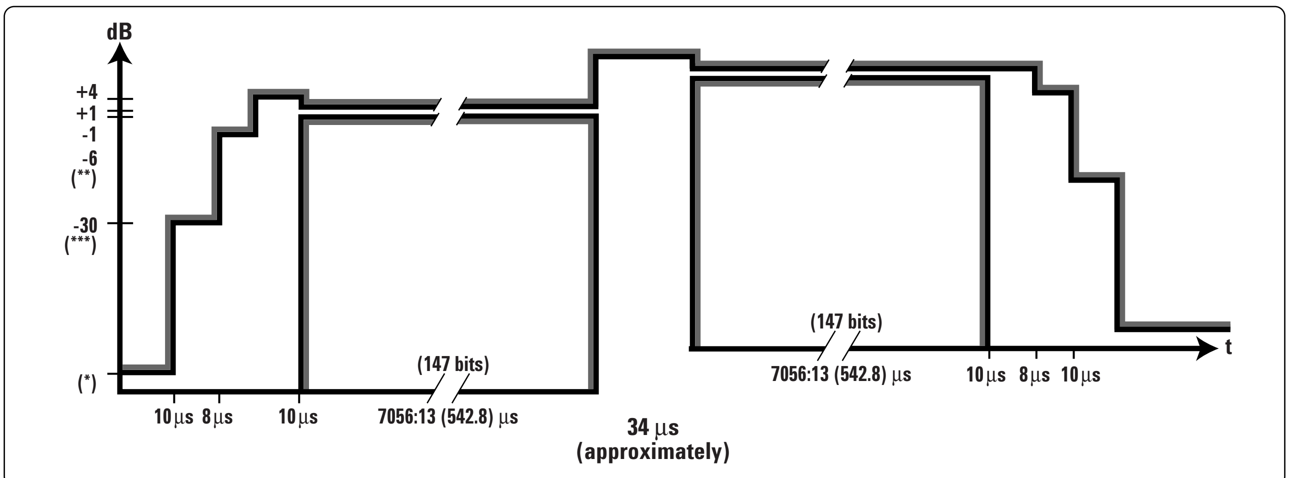

Figure 3. Specification for uplink power vesus time mask

1.3 GPRS without test

GPRS is the first extension of GSM to be defined without a requirement for third-party type approval. This leaves the responsibility for design verification with the manufacturer. With many early MS designs failing to function adequately on the network, it can already be seen how freedom to not fully adopt the mandatory standards within GPRS, coupled with a lack of test, has disrupted Network Operator progress, i.e. not all mobiles work on all networks. This will affect roaming.

Testing offers an alternative to third-party type approval by providing consistency of standards across the industry. Without manufacturers adopting a clear test policy for GPRS it is expected that a significant number of MSs may display sub-optimal performance. Consequently, further difficulties can be predicted for the industry.

Current estimates suggest that an NOP spends on average $700 to attract each new subscriber. In an industry approaching some level of saturation, the NOP must work hard to retain this customer through new features, benefits, and services. With the failure of WAP and other data services to take a serious hold on the market, it is crucial that NOPs generate high expectations for what GPRS will provide. They have to deliver on these expectations if they are to allow the market to regain lost momentum.

These issues are important not only for GPRS but also to ensure that W-CDMA will be given the best possible launch platform. GPRS will be the first format designed primarily for data and will set the benchmark for user experience. NOPs hoping to dispel the negativity around WAP must use GPRS to demonstrate the value of MS data. The key will be to provide services that are both useful and enhanced by higher data rates.

If GPRS connections fail, are slow, or unreliable, it will only confirm the market's suspicions that MS data is not a technology that offers real benefit. This is the concern of the NOPs but should also be considered by the NEMs who rely on the NOPs to provide the services to sell their products. In order to avoid disappointing users, the industry must agree on a set of tested standards for the operation of MSs on GPRS networks.

2 Methods of testing GPRS

As GPRS is a packet-based, connectionless system you are faced with a problem when determining a method of test. In GSM it is easy to set the MS into continuous transmission and reception (just by making a call). In GPRS, the MS only transmits and receives when transferring data. As a result, a method is needed by which the MS can be forced into continuous communication. There are four ways to approach GPRS test. These are described in the sections 2.1.1 through 2.1.3.

2.1 Test modes

2.1.1 BLER test mode

The BLER connection mode is an Agilent-proprietary (patent applied for) method that makes use of standard signaling messages. This method uses a packet ack/nack count from the mobile to compute the BLER. To make an acknowledgement the MS must transmit. By keeping a count of blocks that are received with, and without error, it is possible to assess how well the MS receiver is coping with incoming data.

This connection method sends GPRS Mobility Management (GMM) information messages to the mobile with the polling bit set. This forces the mobile to respond with ack/nack messages, which allows the test set to compute BLER. There are some additional user configurable features in Agilent BLER mode that improve the reliability of this connection method for different manufacturers' mobiles. For example, by default a message is sent to the mobile in every block. This can cause some mobiles to be over-run. To counteract this the polling rate can be slowed down. Another situation that can occur is that mobiles can respond to the GMM information message in different ways. In some cases this causes the mobile to not respond in an appropriate manner. To overcome this problem, the Logical Link Control (LLC) Frame Check Sequence (FCS) can be deliberately corrupted, which forces retransmission of LLC blocks and in turn keeps the RLC/MAC layer transmitting.

Through this, BLER mode provides a method to test both the RX and TX performances of the MS. As described in section 1, both TX and RX measurements are very important for GPRS test.

A strong advantage of this mode is that it does not require any special firmware in the MS. All other GPRS test modes require the MS to be either controlled externally, to produce PRBS internally, or have the ability to loop back data. This is unnecessary with Agilent BLER mode, allowing reliable testing of the mobile early in its development. In fact, any GPRS MS should be able to be tested using this mode.

As this mode of operation uses Radio Link Control/Medium Access Control (RLC/MAC), signaling in what would appear to the MS as normal communication, verifies that the lower layer protocols are functioning correctly.

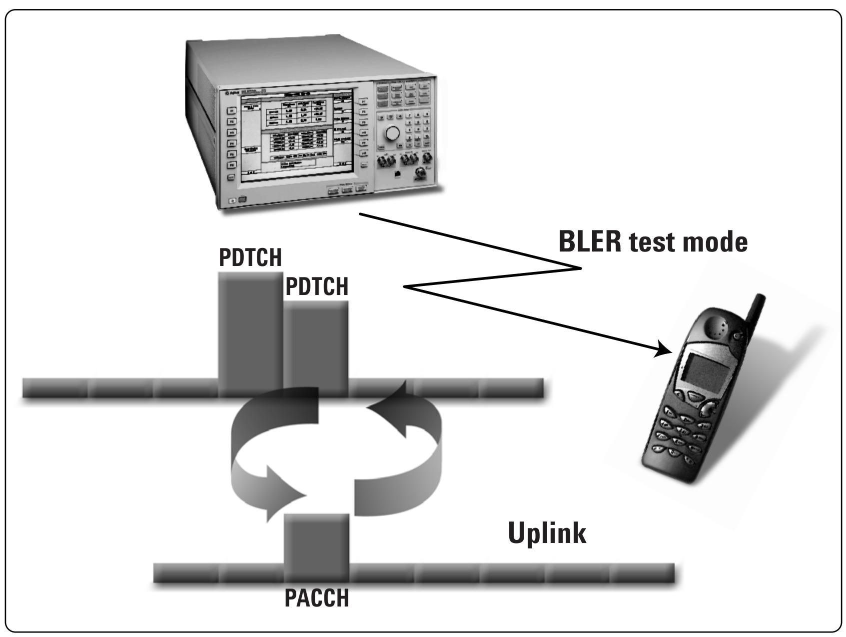

Figure 4. Diagram of BLER connection

2.1.1.1 Using BLER mode to assess receiver sensitivity

If the MS has a minimum sensitivity specification of –x dBm, that is the minimal level at which the MS can receive without error (or with a specified error rate). The base station emulator can be set up in the following configuration to obtain the best results from the test set/MS.

By setting ‘burst 2’ of the downlink close to receiver reference sensitivity level and then setting ‘burst 1’ 10 dB higher than this, you can both ensure that the MS receives the signaling information and stress the receiver of the MS to the maximum. How? In this situation the MS has to cope with a very low-level signal and also with a maximum power level transition specified in the standards. By measuring its BLER you can assess the performance of the receiver in this extreme scenario. If this is set to the specifications for MS sensitivity, then the MS should have a BLER result of <=10%. If there is a value greater than this then there are some issues with the MS's receiver.

This configuration can also be reversed by having the lower power burst first. This assesses the slow rate of the receivers automatic gain control.

Another method for testing receiver sensitivity is to gradually reduce the power of the downlink to see where BLER starts to increase showing the limit of the MS's capabilities.

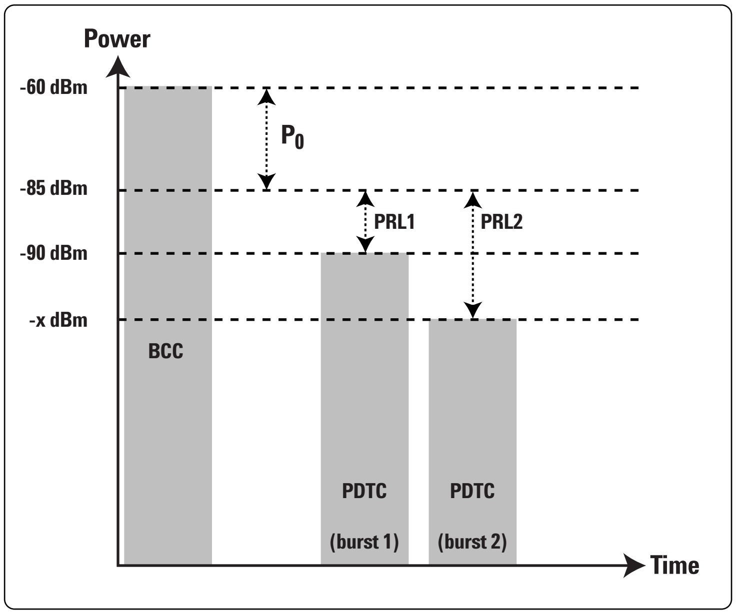

Figure 5. Setting up power offsets and reduction levels

2.1.1.2 What do the specifications say?

The Release 99 GSM 5.05 (now 3GPP 45005) standard refers to the reference sensitivity of GPRS MS. The following table shows the reference sensitivity input levels for GPRS MS in the various bands under static conditions.

The BLER rate in each case must be less than or equal to 10%.

GSM 400, GSM 700, GSM 850, GSM 900, DCS 1800, and PCS 1900	Reference level under static conditions (dBm)
PDTCH/CS-1	-104
PDTCH/CS-2	-104
PDTCH/CS-3	-104
PDTCH/CS-4	-101

The input levels given in the above table are referenced to normal GSM 900 MS and have to be corrected by the following values for other MSs:

GSM 400, GSM 700, GSM 850, and GSM 900 small MS	+2 dB
DCS 1800 class 1 or 2 MS	+4 dB
DCS 1800 class 3 and PCS 1900 class 1 or 2 MS	+2 dB
PCS 1900 class 3 MS	0 dB

Further complication is added by the requirements of the MS to be able to receive data when there is power in adjacent timeslots. There are two situations.

Situation 1 – The MS has to receive data in an adjacent timeslot intended for it, as well as the timeslot in question. In this case, the standards specify that the MS must be able to cope with a difference in power levels between the timeslots of up to 6 dB, without degradation of performance.

Situation 2 – The MS has to be able to receive data in the presence of power in an adjacent timeslot not intended for the MS. In this case the difference in power levels can be up to 20 dB.

2.1.2 ETSI test modes

Due to the requirement for testing of GPRS MSs, ETSI have defined test modes specifically for type approval, these also offer a solution to the manufacture test. They work by forcing the MS to respond to given stimuli over the air interface. These test modes are defined in GSM 04.14 version 6.2.0 Release 1997, Section 5.4. and are referred to as ETSI test mode A and B. ETSI test mode A only allows transmitter testing while B provides the ability to perform transmitter and receiver testing. Although mandatory in the standards many manufacturers have not yet implemented either of the ETSI defined test modes.

2.1.2.1 ETSI test mode A

Once the MS is camped on to the base station signal and has performed a GPRS attach, a downlink Temporary Block Flow (TBF) is established and a “start ETSI test mode A” protocol message is sent over the air interface. (A TBF is a physical connection used by the two Radio Resource (RR) entities to support the unidirectional transfer of Logical Link Control (LLC) Packet Data Units (PDUs) on packet data physical channels.) This instructs the MS to enter test mode A. The configuration of the link (channel, timeslot(s), coding scheme, and such) is managed in accordance with the normal rules for transmission, as defined in GSM 04.60. The MS must then produce its own PRBS (Pseudo-Random Bit Sequence) to fill the data blocks and continuously transmit in every frame.

Once the MS is in a transmitting state, the test instrument can perform transmitter measurements on the MS to ensure that it is within tolerance.

A disadvantage of this mode is that it requires the MS to have special firmware that enables the MS to produce a PRBS to populate the data blocks. Implementing this functionality in the MS can increase development time. Additionally, this mode can only be used for transmitter testing. However, receiver testing is also an important part of GPRS manufacture.

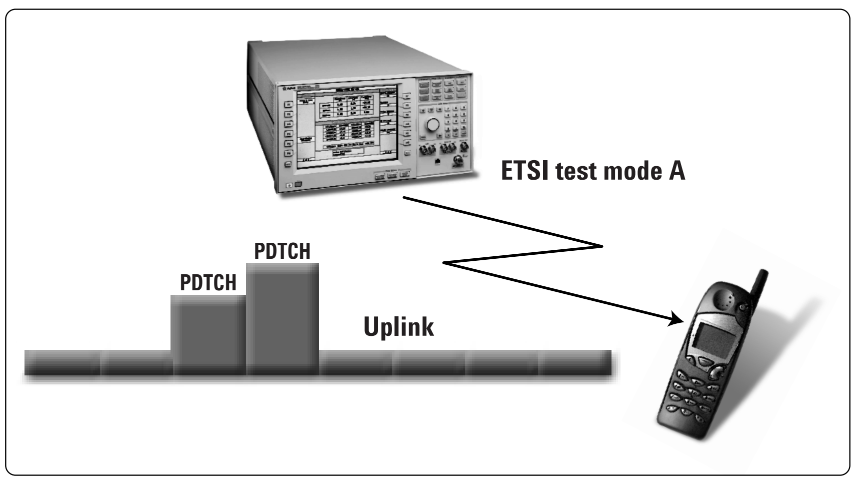

Figure 6. Diagram of ETSI test mode A connection

2.1.2.2 ETSI test mode B

Once the MS is camped on to the base station signal and has performed a GPRS attach, a downlink TBF is established and a “start ETSI test mode B” protocol message sent over the air interface. This instructs the MS to enter test mode B. The configuration of the link (channel, timeslot(s), coding scheme, and such) is managed in accordance with the normal rules for transmission, as defined in ETSI GSM 04.60.

The test instrument sends data blocks on the downlink, containing a pseudo-random data sequence. For the uplink, the data payload of the data blocks contains the data payload previously transmitted to the MS on the downlink. This continues until the test instrument terminates the downlink TBF.

As the MS is looping back the downlink data on the uplink, it is possible to perform a comparison of the data to calculate the Bit Error Rate (BER). Since the MS is transmitting on every frame, the instrument can also make transmitter measurements. For this reason ETSI test mode B offers the greatest scope for testing a MS in GPRS mode. As a result, the industry trend has to be to include ETSI test mode B as a priority over ETSI test mode A. Although BLER also offers receiver testing, BER is a more granular and precise measure of receiver performance. However, the specification for receiver testing is defined in BLER and not BER.

This mode has various advantages and disadvantages. On the positive side, it is an excellent test of receiver and transmitter capability. However, this does require firmware in the MS and can be very difficult to develop.

2.1.2.3 BER testing

When in a loop back situation, it is possible to perform a BER test. This gives an accurate assessment of the capability of the MS's receiver. As GPRS offers asymmetric configurations it is possible that there will be more downlink timeslots used than uplink slots. In this situation it is not possible to loop back all of the downlink data. For a test solution to be truly useful, it is necessary that the user is able to select which of the downlink timeslots to loop back. The reason for this is that the MS will find some transitions more difficult than others. For example, in a multi-downlink configuration with timeslots at different power levels, the MS may have to make different transitions in its automatic gain control – from high to low and low to high. Potentially this offers two situations that the MS can find difficult. If the user is able to select which timeslot(s) to loop back they will also be selecting which of the transitions to test (maybe both).

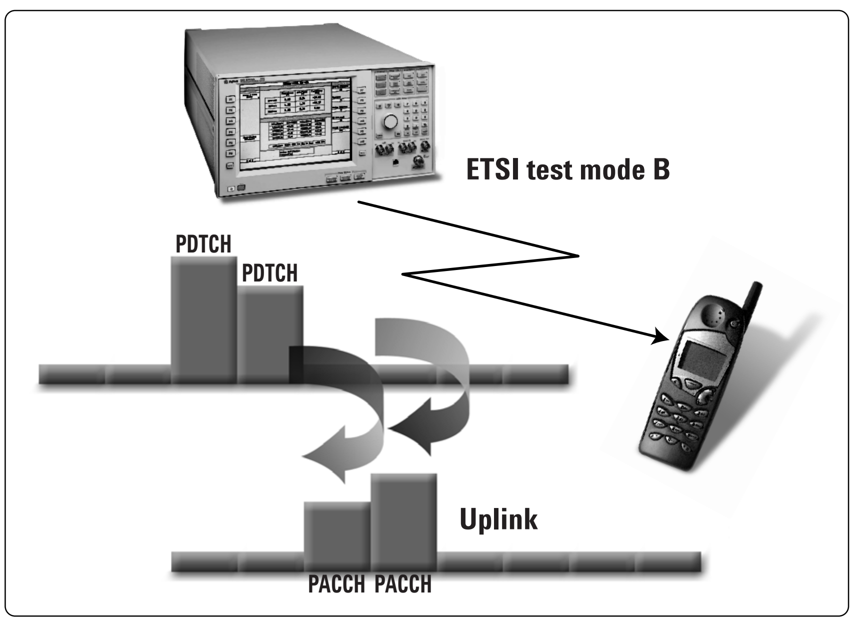

Figure 7 Diagram of ETSI test mode B connection

2.1.3 Manufacturers test mode

This mode of communication is very different to the others. In this test mode the MS and test instrument are controlled completely independently, that is, there is no protocol control between the instrument and the MS. For this to be possible, the manufacturers/developers must have their own proprietary communication method to control their MS. If the MS is only capable of transmitting in this mode you can only make transmitter measurements. However, if the MS can synchronize to the base station signal (BCH) from the instrument and is capable of receiving/looping back the downlink PDTCH, you will be able to perform a BER test and assess the receivers ability.

In GPRS, downlink power control is aided by information contained in the RLC data block header that tells the MS approximately what power to expect. This helps the MS to make adjustments to its AGC. Normally in this type of test mode, all of the data in the block is filled with PRBS. This can cause a problem for the MS if it is using the power reduction (PR) fields in the RLC header to prepare its input circuits. The PR field is two bits in length (see table). In downlink power control (DPC) mode A there are two offsets defined. The P0, which is an offset from the BCCH, and the PR offset. These equate to:

Power reduction bits (PR)	Power reduction
00	0-2 dB less than BCCH level - P0
01	4-6 dB less than BCCH level - P0
10	8-10 dB less than BCCH level - P0
11	Not useable

As can be seen, if this field is filled with random data and the MS is decoding the field to aid reception, the receiver will be disrupted by the values and the BER may be increased.

This test mode is sometimes called instrument test mode, engineering test mode, manufacturers test mode, limited mode, or just test mode.

Test mode has certain advantages and disadvantages. On the positive side it can reduce test time as the MS can be controlled without use of the air interface, removing the necessity for the MS to camp, GPRS attach, and such. However, this requires firmware in the MS, the MS must also be controlled manually or remotely by a PC. This can greatly increase development time. Also by using this type of test mode it is not possible to fully stress the MS.

2.2 Why use a protocol based test mode

If a protocol based test mode is not used, the MS must be controlled individually and any changes to the connection must be applied to both the MS and the test instrument separately. This can greatly increase the development time, as it is necessary to develop the command protocol and have methods for controlling almost every aspect of the MS. However, if you just look at manufacture testing and not development there are still many reasons why GPRS should be tested using a protocol based solution.

- GPRS signaling overhead is far higher than that in GSM. GPRS has to deal with lost blocks, re-transmission, and associated signaling. This signaling overhead varies from MS to MS depending on the exact receiver characteristics and performance. Using signaling gives a much more complete and realistic test of the GPRS MS by adding the stresses a GPRS MS will have to overcome in normal operation.

- Handover performance is critical for GPRS and cannot be tested adequately without signaling. In fact, without signaling it is not possible to perform a true handover. This would just be the MS and instrument re-tuning to a new frequency. More calls are dropped in actual operation during handover than at any other time. This scenario is worse for GPRS data transmission than for voice. A dropped call does not just cause inconvenience. If the MS is in the process of downloading a large file to a PC, it may not be able to just call back and pick up the conversation at the point prior to the call being dropped. The file transfer has to be either partly or completely repeated.

- Using test mode does not allow adequate exercising of the LO/PLL. The MS will not perform the exercise of re-tuning between RX and TX to measure power in neighboring cells using the first entry in the BA table. This is important because the LO/PLL is one area of the GPRS MS that has changed most when compared to GSM MS.

- By using a protocol-based test mode you are verifying the correct functioning of the MS's protocol stack, while this is not truly necessary in manufacture at the early stage of a MS's lifecycle, this is very important.

All of these issues are addressed through adoption of a protocol-based solution.

3 Conclusion

There are many reasons to implement testing of GPRS functionality. The only reason not to test GPRS functionality is to save money. This however, is a short-sited policy, as saving money in the short term (by decreasing overall test time) could cost sales in the long term. Firstly, customers do not want a MS that performs badly since they have to pay for data regardless of whether it contains errors or not. Secondly, NOPs do not want poor quality MSs operating on their networks due to the subsequent increase in traffic and degradation of performance.

There is only one preventative measure to be taken here and that is a solid GPRS testing strategy. In many cases a GPRS testing can be a good indication of the MS performance in GSM mode, the reverse of this is not true. A good GPRS testing strategy should be able to test the majority of GSM functionality and does not have to result in a large increase in test time. It is hoped that this document has some influence on industries' choice of policy thus leading to the successful introduction of high performance devices that will fuel a growth in the age of mobile data communications.

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