

Agilent Developing an EGPRS Mobile Manufacturing Test Plan

Application Note

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Introduction

The typical aim of manufacturing is to optimize throughput: to manufacture as many products that meet specification and quality goals in as short a time as possible with as little equipment and as few people as possible. The production of GSM and GPRS devices is now a well-understood process and most manufacturers have highly efficient production facilities. However, supporting Enhanced General Packet Radio Service (EGPRS) devices may necessitate changes in manufacturing test procedures. For example, the EGPRS modulation format dictates that both the transmitter and receiver capability need additional testing compared to GSM. Consequently, as EGPRS devices are transferred from development to volume manufacturing they create new production test challenges.

This paper explains the unique attributes of EGPRS, which can impact test development. To help engineers create suitable test programs, the paper also explains the strengths and drawbacks of various signalling and instrument test modes. Additionally, a brief overview of what needs considered for RF parametric testing of EGPRS devices is provided.

A Brief Overview of the EGPRS Air Interface

EGPRS devices use two different modulation schemes: GMSK and 8-PSK. This is different from GSM and GSM/GPRS devices, which only use GMSK modulation. The use of two modulation schemes improves the data throughput capability of EGPRS devices compared to their forerunners. For example, when using the 8-PSK scheme, three bits can be transmitted within each symbol as opposed to the one bit per symbol of GMSK.

The 8-PSK modulation scheme is considerably more complex than GMSK. The GMSK scheme is constant envelope and only depends on the direction of the frequency deviation between symbols. In comparison, the 8-PSK scheme is non-constant envelope and depends on eight absolute phase positions, with a $3\pi/8$ rotation between symbols, effectively giving 16 different phase positions. Transitioning between these positions causes both phase and amplitude variation of the signal which, in turn, leads to the RF circuitry being operated in a different manner when transmitting GMSK and 8-PSK signals.

Different modulation coding schemes (MCS) are used across the air interface to cope with varying RF conditions. These are a combination of a modulation schemes (8-PSK or GMSK) and a convolutional coding scheme that provides forward error correction for the data bits being transmitted. Depending on the air interface conditions, different amounts of protection can be applied. Unlike GPRS, for EGPRS none of these schemes are completely clear-coded, meaning they are all subject to convolutional encoding.

Within EGPRS, a mechanism known as incremental redundancy is used to further optimize the utilization of the air interface. In this case, when a radio block is not correctly received, the re-transmitted block will contain different data, which in combination with the original data, improves the chances of the errors in the block being corrected.

The final refinement that EGPRS brings to the air interface is a feature known as link adaptation. This allows the modulation coding scheme in use to be changed dynamically without ending and re-establishing a new connection. This scheme can be used along with the incremental redundancy such that a re-transmitted block can be sent using a different modulation coding scheme.

Production Test Plan Considerations

Optimizing a test plan to test both GMSK and 8-PSK transmitter and receiver performance is challenging. There is obviously a strong desire to not increase overall test times more than necessary, and to not compromise quality through insufficient or inadequate testing. So what is the best way to test the RF capabilities of such a device? The answer depends on a number of factors, such as:

- Is your device capable of transmitting 8-PSK or is it limited to GMSK? (The standards allow for devices that can receive both 8-PSK and GMSK but only transmit GMSK.)
- For a device that can transmit both 8-PSK and GMSK, do you need to test it in asymmetric mode (in other words, receive 8-PSK and transmit GMSK) or can you rely on symmetric mode testing (uplink and downlink are either both GMSK or both 8-PSK)?
- Can you do all your testing with the device under test (DUT) in EGPRS mode or do you need to set up a GSM voice call for audio testing?
- What have the developers of the DUT recommended be tested?
- Do you want to test in a way that maximizes the stress on the DUT (for example, in a signalling mode with the highest rate coding schemes) or do you just want to prove that the RF circuitry works?
- What test modes are available in the DUT? For example, is it ETSI standard modes A and B (developed for GPRS but with some applicability for EGPRS) and/or switched radio block (developed for EGPRS) or some proprietary scheme?
- Can you do receiver and transmitter tests at the same time?
- Do you need to test 8-PSK and GMSK receiver sensitivity or can you infer GMSK results from 8-PSK receiver performance?
- Do you need to do multislot uplink tests? If so, do you need to test under conditions where 8-PSK and GMSK are being used in the same frame? (Even in 8-PSK data transmission, all EGPRS signalling is done using GMSK.)
- How many different power and frequency test points are required for each modulation format?

Once consideration is given to these types of questions, production engineers can prioritize their goals and make choices over how and what to test. The general recommendation is to start off by testing more to verify accuracy and then, as warranted by historic test results, reduce testing over time to improve speed.

Testing in Signalling Mode Versus Instrument Mode

There are pros and cons associated with testing under signalling conditions. In general, signalling is a more realistic test environment, since more parts of the DUT, and therefore the possible effect of these on the RF performance, is being tested. On the other hand there is some overhead time associated with the call set up and management.

If the ETSI standard test modes¹ are implemented in the device or Agilent's proprietary BLER mode is used, then controlling the DUT in a signalling mode can be done by the test equipment, and the equipment will be automatically configured to make accurate measurements. This tends to make the test plan easier to implement.

If not, then the user has to have the means to control the DUT themselves in a non-standard manner and also has to make sure that the test equipment is properly set up to make the desired measurements.

The Agilent 8960 wireless test set supports a number of signalling test modes. The following table shows the suitability of each of these and the instrument test mode for EGPRS transmitter and receiver testing. (**Note:** This table is EGPRS specific, it does not address GPRS.)

	GMSK transmitter test	8-PSK transmitter test	GMSK/ 8-PSK receiver test	Simultaneous 8-PSK down GMSK up
ETSI A	Yes	Yes	No	No
ETSI B acknowledged	Yes	Yes	Yes	No
ETSI B unacknowledged	Yes	Yes	No	No
Agilent BLER	Yes	No	Yes	Yes
Switched radio block (SRB)	Yes	Yes	Yes	Yes
Instrument test mode	Yes	Yes	Yes	Yes

1. The ETSI standard test modes are documented in 3GPP 04.14.

Agilent BLER

This proprietary test mode was originally developed by Agilent to accommodate devices that had not implemented any of the ETSI-standard GPRS test modes.

While it allows both receiver and transmitter testing to be done, it is of limited use for EGPRS testing because the uplink blocks are always signalling blocks and are therefore transmitted using GMSK. It is not possible to make 8-PSK transmitter measurements with this test mode. However, if the DUT is only capable of transmitting GMSK, this is a suitable test mode.

This test mode can be used for both GMSK and 8-PSK BLER measurements based on the DUT returning information as to which blocks were correctly received in response to a poll from the tester. In the case of a multislot downlink, the BLER associated with all the downlinks can be measured simultaneously.

Measurement/Instrument Screen						
Control	GPRS Block Error				PDCH Params	
Block Error Setup ▾	Block Error Ratio 1.93 %				Multislot Config 3 Down, 1 Up	
	Burst	BLER	Power	Block Error Count: 10	1st Burst to Loop	
	1:	0.57 %	-85.00 dBm	Block Delay: ----	1	
	2:	4.71 %	-90.00 dBm		Timing Advance Control ▾	
	3:	0.57 %	-85.00 dBm		Return	
	4:	---- %	---- dBm			
	326 / 500			Continuous		
	Active Cell Transferring		Sys Type: GPRS Logging: Idle			
1 of 2		IntRef	Offset			2 of 2

Figure 1. GPRS block error.

ETSI test mode A

This test mode was originally developed for GPRS. In this mode the mobile only transmits and it does not receive any data from the test set. Its suitability is therefore limited to transmitter testing for either GMSK or 8-PSK. Occasional signalling blocks are transmitted which are always GMSK.

ETSI test mode B

Like ETSI test mode A, this scheme was originally developed for GPRS. It has some applicability to EGPRS testing, but the exact behavior in some cases is likely to be implementation dependent.

ETSI test mode B is a loop-back type of test mode where data sent on the downlink is sent back on the uplink. It is not, however, a layer one loop-back. Higher layers in the DUT's protocol stack are involved. This factor significantly complicates, and possibly compromises, the use of this test mode for EGPRS testing as compared to GPRS testing. At best it is likely to be device- and implementation-specific.

ETSI test mode B cannot be used for situations where different modulation schemes are in use on the uplink and downlink. It cannot be used to fully test mobiles that can receive 8-PSK signals and can only transmit GMSK.

There are two variations of ETSI test mode B: acknowledged mode and unacknowledged mode. This is due to some ambiguity in the standards. Both mode variations have some advantages and disadvantages.

In the acknowledged mode, the DUT is periodically polled. (**Note:** Only the downlink operates in this mode, the uplink is always unacknowledged.) It responds by sending back a message that contains information on which blocks were correctly received, similar in same manner to the Agilent BLER mode. Blocks that are not correctly received are re-transmitted disrupting the PRBS. Strictly speaking, the standards require signals modulated with PRBS data for all measurements.

In the unacknowledged mode this polling does not happen. Bad blocks are not re-transmitted, although the DUT still loops them back as received onto the uplink. This maintains the downlink PRBS, even if blocks are received in error.

In ETSI test mode B, the data sent on the downlink is convolutionally encoded and punctured before modulation and transmission. This data is then convolutionally decoded by the DUT before being re-encoded and sent back on the uplink. Even if the cyclic redundancy check (CRC) fails after the decoding process, the decoded data will be re-encoded and transmitted on the uplink.

One problem with using the looped-back data from test mode B for EGPRS receiver sensitivity measurements occurs because of the high level of puncturing that takes place. This makes it likely that if a certain number or combination of errors occurs, the decoder may fail and incorrectly cause a cascade of errors. These are then re-encoded and sent back on the uplink to the tester, where a similar decoding process is applied with possibly a similar cascade of errors occurring. Therefore, any BER or BLER measurement that depends on comparing the data received on the uplink with that sent on the downlink may be suspect. The precise behavior is likely to be implementation dependent. It may be possible to do BLER measurements in this mode since a block is in error whether one or all the bits in the block are corrupted; but this is not recommended.

The good news is that the ETSI B acknowledged mode can be used for an EGPRS BLER measurement. As previously mentioned the DUT responds to the poll by returning information as to which blocks were correctly received. As with the Agilent BLER mode, the tester can use this information to calculate a BLER measurement. When operating in ETSI B acknowledged mode, the Agilent 8960 uses this method for BLER measurements. A further advantage of this method compared to a loop-back method is that the BLER associated with all the active downlinks can be measured at the same time.

The same PRBS restriction of ETSI B acknowledged mode is true for the transmitter measurements, where, as previously mentioned, measurements should be made on bursts modulated with PRBS data. This is more important for 8-PSK measurements since due to the non-constant envelope nature of the signal it is necessary to average over more bursts to make accurate measurements. As long as uplink and downlink power levels are high enough to avoid decoding problems and retransmissions, then there is unlikely to be any problem with this approach. This may make the use of ETSI B acknowledged mode for simultaneous transmitter and receiver measurements suspect, since in this case the downlink power is deliberately reduced leading to a higher likelihood of data being received in error and therefore re-transmitted.

Switched radio block (SRB) loop-back

This ETSI standard test mode, sometimes known as ETSI test mode C, was specifically developed to address the problems of testing EGPRS devices. In this mode, the mobile is put into a layer one loop-back mode by the test equipment, where all data sent on the downlink is transmitted unchanged on the uplink. In other words, the data is not passed through the decoder of the DUT before being re-transmitted. This gets around the problem of there being no clear-coded EGPRS modulation coding scheme and allows both transmitter and receiver measurements to be made simultaneously.

This is likely to be the most efficient signalling-based test mode since transmitter and receiver tests can be made at the same time. SRB mode as defined in the standard also allows for the uplinks and downlinks to use different modulation formats. This means that mobile devices that can receive 8-PSK and only transmit GMSK can be tested with this test mode.

Instrument test mode

This mode requires the user to control the behavior of the phone and test equipment independently. While this can be an efficient method for doing testing, its disadvantages include having to build proprietary test modes into the phone and not being particularly stressful for the mobile. That said, it may be easier to control the interspersing of GMSK and 8-PSK uplink bursts, either on the same or successive frames.

Making the Choice

The choice as to which signalling test mode or combination of test modes to use will depend on what has been implemented in the phone, how much stress you want to put the DUT under, and how fast you want to be able to make all the required measurements.

It is likely that both GMSK and 8-PSK transmit capability will need to be tested because the DUT's power amplifiers will be operated in different regions for these modulation schemes. GMSK is constant envelope; therefore the amplifiers are typically operated in saturation which is the most efficient mode. 8-PSK modulation is non-constant envelope, so it is necessary to operate the amplifiers in the unsaturated region. This leads to additional possible signal impairments such as compression (amplifier being driven into saturation) and amplitude droop (signal amplitude varying across the burst.)

It is possible that depending on the DUT implementation, only 8-PSK receiver sensitivity testing need be done with a GMSK result being inferred.

SRB, ETSI B acknowledged, and instrument test modes each allow simultaneous transmitter and receiver measurements to be made, but with the various advantages and disadvantages noted above. If available, SRB is probably the most useful and versatile single mode.

Another alternative might be to use a combination of ETSI test mode A for 8-PSK transmitter measurements and Agilent BLER mode for 8-PSK receiver and GMSK transmitter testing. Agilent BLER mode has the additional benefit of functionally testing the DUT with an 8-PSK downlink and a GMSK uplink.

The good news is that since both GMSK and 8-PSK modulation schemes are part of EGPRS, it should not be necessary to re-test the RF parts of the mobile under either GPRS or normal GSM voice operation; although it may be necessary to set up a voice call for audio testing. In other words, it should be possible to do all the RF testing of the mobile in EGPRS mode.

If raw speed is the uppermost consideration, then it is worth considering using the instrument test mode with the user controlling both the phone and instrument set up.

Other RF Measurement-Related Topics

The detailed description of measurements is beyond the scope of this paper, however this section gives a brief overview of what needs should be considered for RF parametric testing of EGPRS devices. The conformance test standard is 3GPP 51.010. The engineer needs to determine what subset of tests needs to be carried out in production.

8-PSK measurements present additional test plan challenges. The principles of what to measure, such as power and timing accuracy, and out of channel interference, are the same for both GMSK and 8-PSK; however the non-constant envelope nature of the 8-PSK signal means that making accurate measurements is considerably more complex. The specific envelope of the 8-PSK signal depends on the modulating data, making the measurements statistical in nature. This means that accurate measurements typically require a number of bursts modulated with PRBS data to be averaged.

Another consideration for multislot capable mobiles is that since both GMSK and 8-PSK schemes can be used within the same frame on successive bursts on both uplink and downlink, the parametric performance of the mobile as it rapidly switches between these formats may need to be tested.

A further need is to make sure that the test equipment used is able to ignore bursts of the modulation type not being measured. So, when making an 8-PSK measurement, GMSK bursts received should be ignored and vice versa which is particularly important for averaged measurements. The Agilent 8960 EGPRS applications detect which type of burst was received and take the appropriate action to either measure or ignore it.

Power measurements

Due to the non-constant envelope nature of the 8-PSK signal, making an accurate carrier power measurement requires averaging a large number of bursts. This obviously takes more time than the equivalent GMSK test that can be made on a single burst. Agilent has taken steps to address this by offering an estimated 8-PSK carrier power measurement that can make a measurement within the accuracy required by the standards based on only a single burst.

Power versus time

The principle of power versus time (PvT) is similar for both GMSK and 8-PSK, although the masks are plainly different. However, as mentioned above, for a multislot uplink it may also be worth considering the case where one uplink is GMSK and the other is 8-PSK.

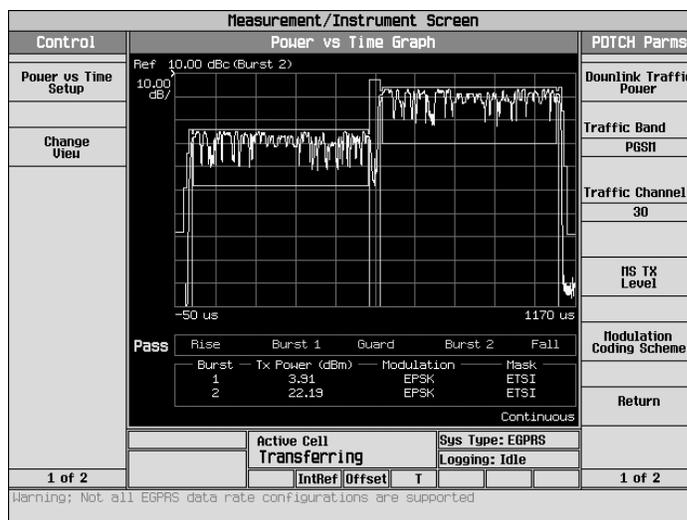


Figure 2. Power versus time.

Modulation accuracy

This is by far the most complex 8-PSK measurement and is very different from the relatively simple phase frequency error (PFER) measurement used for GMSK. It returns a number of different parameters related to the modulation accuracy of the burst. This measurement can show up a number of different signal impairments including

- amplitude droop across the burst
- origin offset
- compression
- IQ imbalance

The primary modulation accuracy measurement is error vector magnitude (EVM), which measures how far away the transmitter's position on the phase diagram is from the ideal. As for the other 8-PSK measurements, the varying of the signal from symbol to symbol and burst to burst requires a statistical approach and the standards are written in these terms. For example, the standards specify root mean square (RMS) and 95th percentile performance for EVM.

This measurement will be important for manufacturers attempting to optimize the battery life by transmitting at the lowest power level allowable within the standards for each power step. For GMSK, the signal amplitude has no effect on the modulation accuracy. For 8-PSK, the signal amplitude does affect the modulation accuracy.

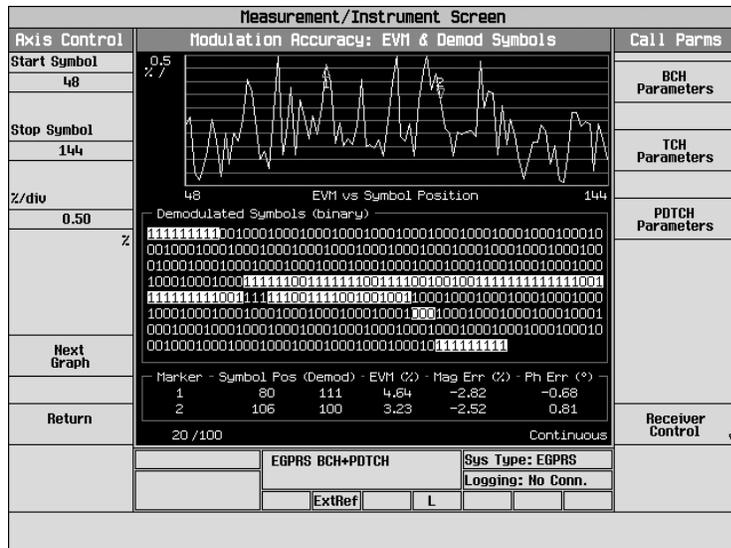


Figure 3. Modulation accuracy.

ORFS

This measurement is very similar for both GMSK and 8-PSK, the only difference is that a different test limit at the ± 400 KHz offsets.

Conclusion

The development of an optimal test plan for EGPRS mobiles is not a simple undertaking. The choices are largely governed by the test modes available in the phone; whether ETSI standard or a proprietary mode.

The production engineers need to prioritize their goals in terms of speed and accuracy and then make disciplined choices over how and what to test. The general recommendation is to start off by testing more to verify accuracy and then, as warranted by historic test results, reduce testing over time to improve speed.

For signalling-based testing, the ETSI standard SRB mode is recommended if available, followed by the ETSI B acknowledged mode. If neither of these is available, then some combination of modes such as ETSI A and Agilent BLER may be the best choice.

For measurements, the ability to use techniques such as the Agilent 8-PSK estimated carrier power measurement can do much to reduce test times without compromising accuracy. If possible, simultaneously testing transmitter and receiver measurements is plainly another good choice.

Glossary

BER	Bit error rate
BLER	Block error rate
CRC	Cyclic redundancy check
DUT	Device under test
EGPRS	Enhanced general packet radio system
ETSI	European Telecommunications Standards Institute
EVM	Error vector magnitude – primary modulation accuracy measurement for 8-PSK
GMSK	Gaussian minimum shift keying – modulation scheme used within GSM, GPRS, and EGPRS
8-PSK	8-phase shift keying – modulation scheme used within EGPRS
GPRS	General packet radio system
GSM	General system for mobiles
IQ	In-phase quadrature
MCS	Modulation coding schemes
ORFS	Output radio frequency spectrum – a measurement of how much energy falls outside the assigned channel
RF	Radio frequency
RMS	Root mean square
PvT	Power versus time
PFER	Phase frequency error – the modulation accuracy measurement used for GMSK
PRBS	Pseudo-random binary sequence
SRB	Switched radio block – an ETSI standard test-mode for EGPRS devices

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