State-of-the-Art Mobile Radio Measurements
Educational Note

Products:

▪ R&S®CMW500

The topic of this application note is mobile phone measurements – in theory and in practice. It discusses measurements according to the most common standard in use today, GSM.

The first, theoretical portion of this application note covers digital modulation and access methods in general. This is followed by an overview of the specific characteristics of the GSM standard as well as a summary of the most important mobile radio measurements.

The second, practical portion of this application note covers some of these measurements in detail and runs through them step by step. These measurements can be performed by small groups in labs.

The measurements and analysis of the results are intended to illustrate the theoretical portion of the application note and to deepen the reader's understanding.

All measurements are performed using the R&S®CMW500 wideband radio communication tester and an off the shelf mobile phone.

ROHDE&SCHWARZ

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Note: In this document the wideband radio communication tester R&S®CMW500 is referred to as the CMW500 or CMW.

1 Overview

The topic of this application note (1MA231) is mobile phone measurements – in theory and in practice. It discusses measurements according to the most common standard in use today, GSM.

At first, in the theoretical portion of this application note, chapter 2 introduces digital modulation and access methods. Then chapter 3 explains why the mobile radio measurements are important, and it organizes the many tests into a comprehensible structure. Chapter 4 provides an overview of the specific characteristics of the GSM standard. Finally the tests used to verify the critical RF characteristics of a mobile phone are also listed in this chapter.

Mobile radio tests in signaling mode, as discussed in this application note, follow always the same sequence of steps. This sequence is presented in chapter 5, before the practical exercises using the R&S®CMW500 wideband radio communication tester.

Chapter 6 begins the practical portion of the application note. This section first describes how to use the CMW500. Chapter 7 covers the creation of a universal, reproducible CMW configuration as a basis for all subsequent measurements.

The practical exercises include

- Burst Power and Timing (chapter 8)

- Modulation Quality (chapter 9)

- Frequency Spectrum (chapter 10)

- RX Sensitivity (chapter 11)

These exercises can be performed by small groups in a lab. The measurements and analysis of the results are intended to illustrate the theoretical portion of the application note and to deepen the reader's understanding. Questions are included to check understanding of the concepts.

All measurements are performed using the R&S®CMW wideband radio communication tester and an off the shelf mobile phone.

2 Digital Wireless Communications

2.1 Digital Modulation Methods

Digital wireless communications is a sophisticated, practical application of communications engineering that involves the acquisition, storage, processing and transmission of data messages (information).

This application note focuses on the latter, i.e. the transmission of information. It is assumed that this information is already available in the form of digital data streams. In wireless communications, this information includes voice coder data, user data (data services) and signaling information[1].

Digital data streams consist of pure information; they are dimensionless and have no particular time reference. As a result, it is no problem to store these streams so that they can then be transmitted more quickly or more slowly than they were originally sampled, for example. It is also very easy to change the coding of certain segments, to add redundancy information, to change the sequence, to repeat segments, to correct transmission errors and to multiplex different data streams together. The requirements of a modern wireless communications system to

▪ transmit voice, data and signaling information more or less simultaneously,

▪ encrypt conversations to prevent interception,

▪ guarantee that a maximum number of transmission errors is not exceeded (quality of service, QoS) and

▪ transmit and receive discontinuously (e.g. in timeslots)

are therefore relatively easy to implement using digital data and digital signal processing, or at the very least it is significantly easier than with analog technology.

Digital signal processing also permits other important operations, such as data compression, filtering or echo and channel equalization. And one of the crucial requirements for modern wireless communications was the invention of highly efficient voice codecs (coder / decoder) that were able to adequately reduce the data rate required for voice transmission.

Finally, it makes sense to couple digital data processing with digital modulation methods in wireless communications.

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[1] Signaling information is control data not visible to the user that is automatically included in the transmission in order to establish, maintain and clear down a radio link.

Principles of I/Q modulation

Conventional analog modulation modes vary the signal from an RF carrier in only <u>one</u> dimension.

Amplitude modulation changes only the amplitude ρ(t), while frequency and phase modulation affect only the frequency or the phase φ(t) of the carrier, respectively. Amplitude modulation takes place primarily at the RF output stage, and the frequency and phase modulation take place at the oscillator stages. The modulation signal has the same waveform as the wanted signal.

State-of-the-art I/Q modulators vary the RF carrier signal in <u>two</u> dimensions.

They synthesize the modulation signal from the sum of two baseband signals, i(t) and q(t), where i(t) represents the inphase component and q(t) the quadrature component. Applied orthogonally, the two span one vector in the I/Q layer, with length ρ(t) and phase φ(t), see Fig. 2-1. The values of i(t) and q(t) are normalized, i.e. always ≤ 1.
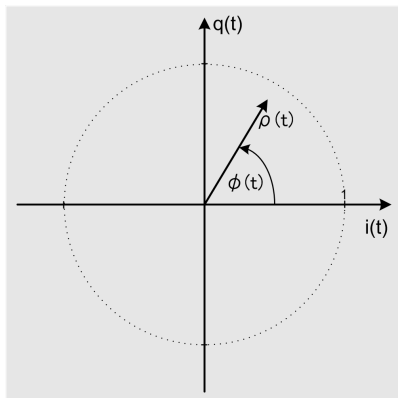
Fig. 2-1: Baseband vector in the I/Q layer.

The modulated RF signal is generated by adding one carrier modulated with i(t) and one modulated with q(t) – but phase-shifted by 90°, see Fig. 2-2.
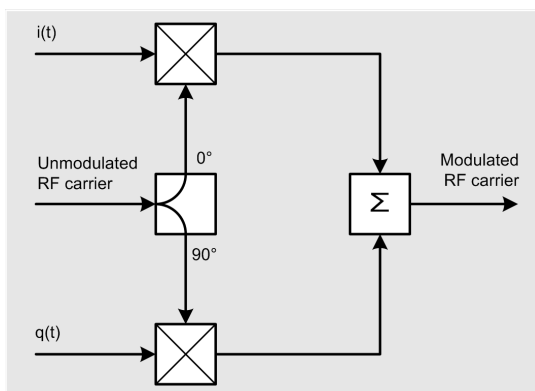
Fig. 2-2: Upconversion of the baseband signals.

By using two baseband signals, it is possible to determine the magnitude as well as the phase of the modulated signal at any given point in time. This also makes it fairly easy to implement analog modulation:

Amplitude modulation is performed by varying the length of the vector ρ(t) versus time without changing the phase. Frequency and phase modulation involves varying the phase φ(t) of the overall vector without changing the amplitude.

Digital I/Q modulation

The smallest message / information elements that are transmitted over the air interface during digital modulation are called symbols. Symbols combine – depending on modulation mode – n individual bits, where n is taken from the set of natural numbers. These symbols form the set of numbers used by a modulation mode. The throughput of the air interface is determined by the symbol rate and the number of bits per symbol.

The number of possible symbols for a digital modulation mode is finite and countable. (It is 2^n, which is how many numbers can be represented with n bits.) Now, for each symbol, a specific I/Q vector (I/Q mapping) or a specific vector change is defined in a so called constellation diagram.

For digital I/Q modulation, therefore, the I/Q vector takes up a finite, countable number of states or changes with a specific amplitude and phase. When considered in this light, digital modulation is nothing more than analog modulation with a finite number of discrete states.

GSM uses Gaussian filtered minimum shift keying (GMSK), which is a hybrid of analog and digital modulation. It represents an optimized form of phase modulation. In this case, a symbol is made up of one bit. The two possible logical states are realized by shifting the I/Q vector by +/– 90° (+/–π/2). Unchanging bits on the physical layer result in a continuous phase shift of +90° per symbol, while a permanent bit change leads to a continuous phase shift of –90°. In the spectrum, this results in a frequency shift of +/– 67.7 kHz, which is one quarter of the symbol frequency. The level of the modulated signal, i.e. the length of the I/Q vector, remains constant.

Constellation diagrams (examples)

The following figures show the constellation diagrams for several modulation modes. In keeping with convention, only the end points of each I/Q vector are shown. I has to be stated that the I/Q vectors have to attain the constellation points only at the active edges of the symbol clock exactly. Transitions occur between those points in time. These transitions will be discussed later.

The constellation diagrams shown below are used in the standards GSM and 3GPP UMTS. There are other systems, some extremely complex. The individual standards differ on which I/Q vector belongs to which symbol. Therefore, the bits and bit combinations shown in the following constellation diagrams are examples only; other allocations also exist.

The binary phase shift keying (**BPSK**) modulation transmits only one bit per symbol. There are therefore $2^1 = 2$ different symbols or states. The symbol rate is equal to the bit rate.
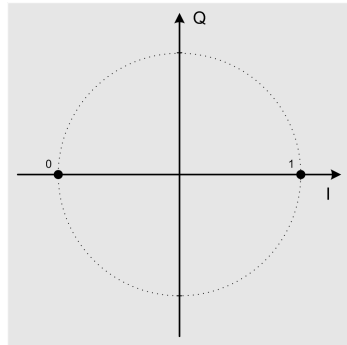
Fig. 2-3: Constellation diagram for BPSK.

The Gaussian filtered minimum shift keying (**GMSK**) modulation also transmits only one bit per symbol. Because the modulation is performed by a phase shift of +/– π/2, there are theoretically exactly 4 possible states at the (active edge of the) symbol clock. Depending on the history however, the filtering typical for GMSK can result in an actual phase shift of somewhat greater than or less than exactly π/2. For this reason, each quadrant has three possible positions at the symbol clock (intersymbol interference, ISI). Because the modulation information lies in the direction of the shift, the "states" cannot be assigned a logical null or one. The CMW500 wideband radio communication tester therefore displays a circle in the I/Q diagram for GMSK.
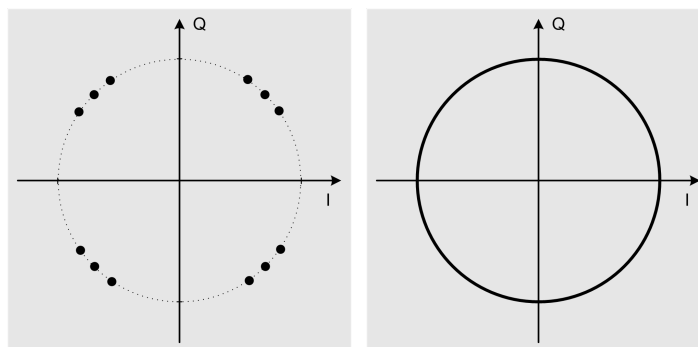
Fig. 2-4: Constellation diagram for GMSK; display on the CMW500 (right).

Quadrature phase shift keying (**QPSK**) modulation transmits two bits per symbol. It therefore provides $2^2 = 4$ different symbols. The symbol rate is the bit rate / 2.
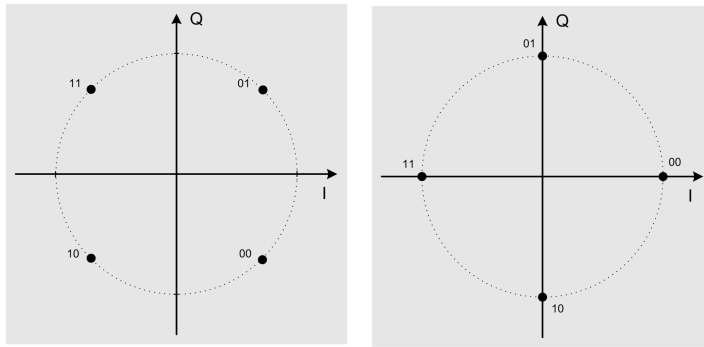
Fig. 2-5: Constellation diagrams for QPSK.

As seen here, it is possible to "hop" to any state from any other state. In contrast to GMSK, the entered positions correspond to defined symbols.

The 8-phase shift keying (**8-PSK**) modulation transmits three bits per symbol. It therefore provides $2^3 = 8$ symbols. The symbol rate is the bit rate / 3.
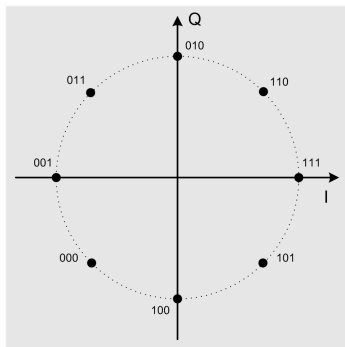
Fig. 2-6: Constellation diagram for 8-PSK.

The 16-quadrature amplitude modulation (**16-QAM**) transmits four bits per symbol. It therefore provides $2^4 = 16$ symbols. The symbol rate is the bit rate / 4.
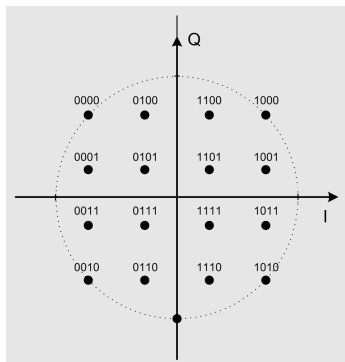
Fig. 2-7: Constellation diagram for 16-QAM.

As seen here, with "higher" modulation. the unit circle and the area inside the circle are used more efficiently to distribute symbols in the I/Q layer.

To anticipate, transmission of a signal with a symbol rate of $1 / T_{symbol}$ requires (approximately) one radio channel of the same bandwidth in the RF frequency range. Stated conversely, for any given channel width, the maximum possible <u>symbol</u> rate is fixed. The maximum transmission rate in bits therefore increases as the number of bits contained in a symbol increases (i.e. the higher the order of the modulation).

However, as the number of symbols increases, the spacing between adjacent states must decrease. As a result, the symbols are more difficult to separate on the receiver end, especially when they are accompanied by noise from a poor radio link.

This is why the digital 256-quadrature amplitude modulation (**256-QAM**) as shown in Fig. 2-8 is not used for GSM and 3GPP UMTS. However, 256-QAM and other higher-order modulations are used in low-noise broadband cable networks with reliable levels. 256-QAM transmits eight bits per symbol. It provides 2^8 = 256 symbols. The symbol rate is the bit rate / 8.
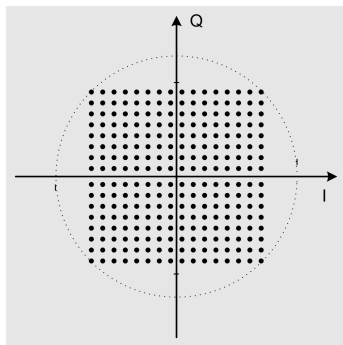
Fig. 2-8: Constellation diagram for 256-QAM.

The higher order the modulation – i.e. the narrower the symbol spacing – the closer the discrete modulation comes to a continuous modulation with respect to the use of amplitude and phase. However, it must be noted that the I/Q vector changes per unit of time is relatively low in analog modulation, while it is typically fairly high for digital modulation. The I/Q vector must "hop" back and forth between random symbol positions.

Error vector magnitude

The error vector specifies how much the I/Q vector of a real system (at the symbol clock) deviates from the ideal constellation point. These types of deviations are caused primarily by circuit unsymmetries and nonlinearities, by amplitude and phase noise and by unwanted signals. Error vector magnitude (EVM) is the ratio of the magnitudes of the error vectors to an average vector length calculated from the lengths of all undegraded I/Q vectors. EVM is expressed in dB or as a percentage.

High EVM values mean that the correct symbols will not always be correctly detected during signal recovery. The EVM is therefore an important measure of modulation

quality and is always part of the TX measurements on mobile devices. The peak value and RMS value are typically measured.

It is apparent that higher-order modulations (with narrower symbol spacing) will respond more sensitively to vector errors than simpler modulations (with wider spacing). Fig. 2-9 shows on the left the constellation diagram of a QPSK signal shifted by 45° in a scenario with carrier/noise (C/N) of 20 dB. The peak EVM in this case is 25.8 %, and the symbol recognition is only slightly at risk. On the other hand, the symbol approximation for the 16-QAM signal shown on the right in Fig. 2-9 is only partially correct, although the C/N is the same.
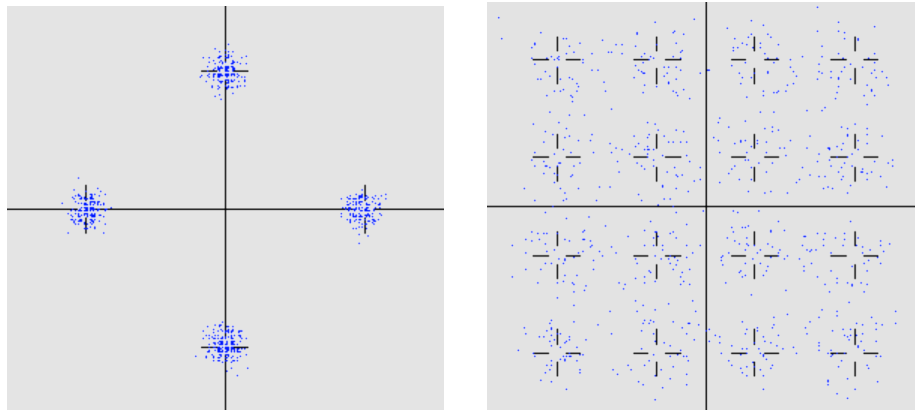
Fig. 2-9: Constellation diagrams for QPSK and 16-QAM with the same C/N.

Although the signal and the noise power is the same for the signals in the figures on the left and the right, the peak EVM for 16-QAM on the right is 47.9 % instead of the 25.8 % for QPSK. This is because the average I/Q vector length used for the calculation of the error vector is significantly smaller for 16-QAM than it is for QPSK.

Note: For GMSK no EVM can be specified because the intersymbol interference makes it impossible to specify an unambiguous I/Q vector!

Filtering

If digital data is converted to electrical time domain signals, these need be valid exactly only at the active edge of the symbol clock. The constellation diagram shows only these states, not the state transitions. However, it is the transitions that are significant for the spectrum and for the demodulation of the signal.

When sequential data is varied, the instantaneous value changes abruptly. While this is possible without any problem in computational signal processing, that is not the case in physical reality, with the ever-present band limitations. Steep edges are additionally undesirable in practice because they generate a broad frequency spectrum. Each

mobile radio signal must stay within the bandwidth of an allocated channel so that it does not degrade radio links from either the current provider or from other services.

For this reason, the transmit signal is filtered. With digital signal processing, this can take place in the baseband. This has several advantages over filtering the later RF signal:

▪ The filtering does not require any hardware components, as it is purely digital.

▪ A lowpass filter is sufficient in the baseband; no bandpass filter is required.

▪ The filter parameters remain constant. An adjustable filter is not needed (such as would be required for the various channel frequencies in the RF domain).

Each filtering will always cause smoothing of the transitions. Fig. 2-10 shows the shape of filtered baseband signals i(t) and q(t). This is a 3GPP UMTS signal (dual BPSK signal).
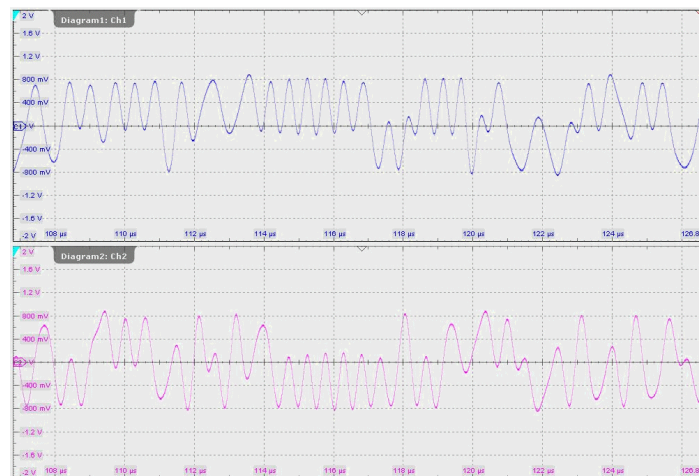
Fig. 2-10: Filtered I/Q signals.

These signals no longer have any resemblance to abrupt data changes.

Fig. 2-11 on page 13 shows the position of the I/Q vector at the symbol clock on the left and the continuous progression on the right. As a result of filtering, this no longer follows the shortest direct connection between the symbols, but rather describes the transients.
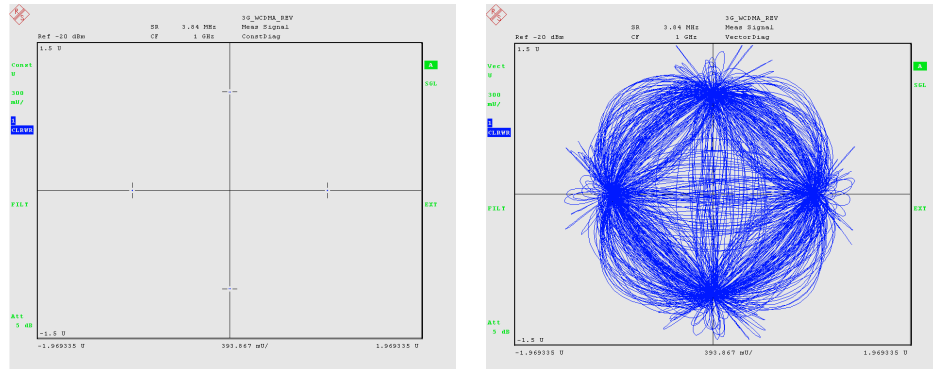
Fig. 2-11: Constellation (left) and continuous vector display.

To permit i(t) and q(t) to perform these smooth transitions, the clock frequency of the digital signal processing must be greater than the symbol change frequency.

Crest factor / linearity requirements

The amplitude of the later RF transmit signal is always proportional to the corresponding vector length in the baseband – also between the active edges of the symbol clock. Looking at Fig. 2-11, we see that the I/Q vector exceeds the unit circle between the symbol points. The ratio of peak value to average value is called the crest factor. It determines the power margin that must be reserved at the TX output stage.

Signal breaks also occur. partly down to zero (origin), see Fig. 2-11.

To be demodulated without errors at the receiver end it is very important to transmit the original signal shape without distortion. The transmit output stage must therefore not only maintain some headroom, but in the case of Fig. 2-11 also exhibit very high linearity over the entire range from 0 watts to the maximum power.

GSM primarily uses the two modulation modes GMSK and 8-PSK.

Ideally for GMSK, the I/Q vector will remain exclusively on the unit circle. The crest factor is 1; theoretically there are no power peaks or amplitude notches.

With 8-PSK, the zero crossings during hops between opposing symbols in the I/Q diagram are avoided by rotating the constellation diagram by 3π/8 between the symbol clocks. The vector diagram (Fig. 2-12 on page 14) demonstrates the desired effect. The transmit power we will observe during the measurements shows level drops of about 12 dB during data transmission, but not all the way to zero, see Fig. 2-13 on page 14 . The linearity requirements for the TX output stage are somewhat moderated.

As a result of the rotation, about 16 symbol states will be recalculated at the receiver end.
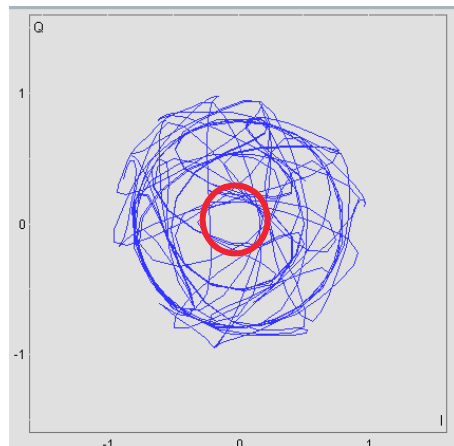
Fig. 2-12: Maintaining a zone around the origin by rotating the constellation.
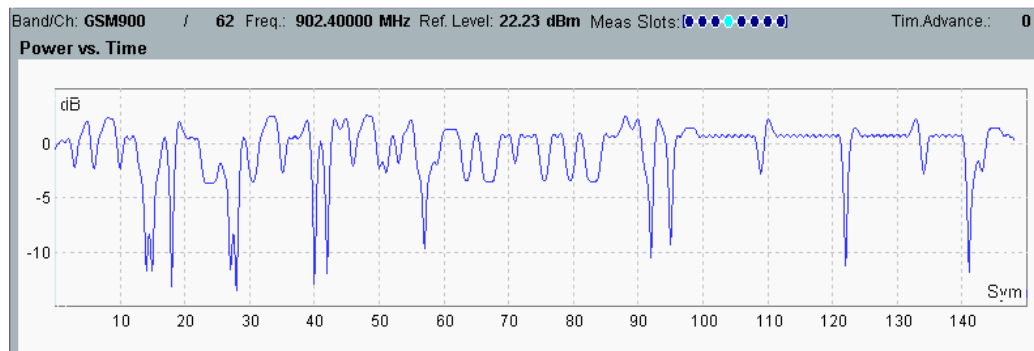
Fig. 2-13: Shape of the envelope power vs. time for an 8-PSK-modulated signal.

Filter types

The filter types and parameters are mandated by the individual wireless communications standards.

The GSM standard uses Gaussian filters. Their characteristics mean that the position of the vector in the I/Q diagram at the symbol point in time is dependent to some degree on the preceding symbol (intersymbol interference, ISI). This filter type was chosen primarily because it prevents level overshoot in the time domain. During the data transmission (in the useful part of the burst), a GMSK signal displays a constant envelope. This ensures that any nonlinearities in the transmitter and receiver will not affect the transmission quality. (The ISI is compensated by an equalizer at the receiver end.)

The 3GPP UMTS standard uses cosine filters that are dimensioned in accordance with the (second) Nyquist[2] criterion. In an ideal scenario, their symmetrical edge characteristics make it possible to eliminate the intersymbol interference completely.

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[2] Named after researcher Harry Nyquist.

Depending on the system, the modulation used in the 3GPP UMTS standard requires amplifiers with very high linearity and dynamic range. Some overshoot can be tolerated.

The filtering can be divided between the TX and the RX ends. The composite filter then assumes the characteristics of the product of the individual transfer functions. For 3GPP UMTS, therefore, root raised cosine filters are used at both the TX and RX end.

Required filter bandwidth and spectrum

In a binary data stream, the greatest fundamental frequency (first harmonic) occurs when zeros and ones are continuously alternated. A "period" is two bits in duration.

When the data with symbol frequency $1 / T_{symbol}$ is received, the highest frequency in the data stream is $1 / (2 * T_{symbol})$. Other bit sequences generate lower frequencies. This highest frequency is called the Nyquist frequency.

As a rule of thumb, the necessary bandwidth in the (complex) baseband must at least match the Nyquist frequency. The modulated RF signal uses double the bandwidth.

In the case of GSM, the doubled Nyquist frequency lies at approximately 270 kHz, while the radio channel spacing is only about 200 kHz. As a result, signals could interfere with immediately adjacent channels. This must be taken into consideration when planning the frequencies for the radio cells.

In the case of 3GPP-WCDMA (3GPP UMTS) the doubled Nyquist frequency is 3.84 MHz and the channel spacing in the frequency grid is at least 5 MHz. A review of the adjacent channel leakage ratio (ACLR) will ensure that the mutual interference from adjacent channels remains low.

Building blocks for the wireless transmission chain

Fig. 2-14 provides a schematic overview of the cooperation between digital and analog functions at the transmit and receive ends of the transmission chain. This overview shall be considered as a basic block diagram because it displays the processing steps for only one wireless communications subscriber or for only one radio channel.
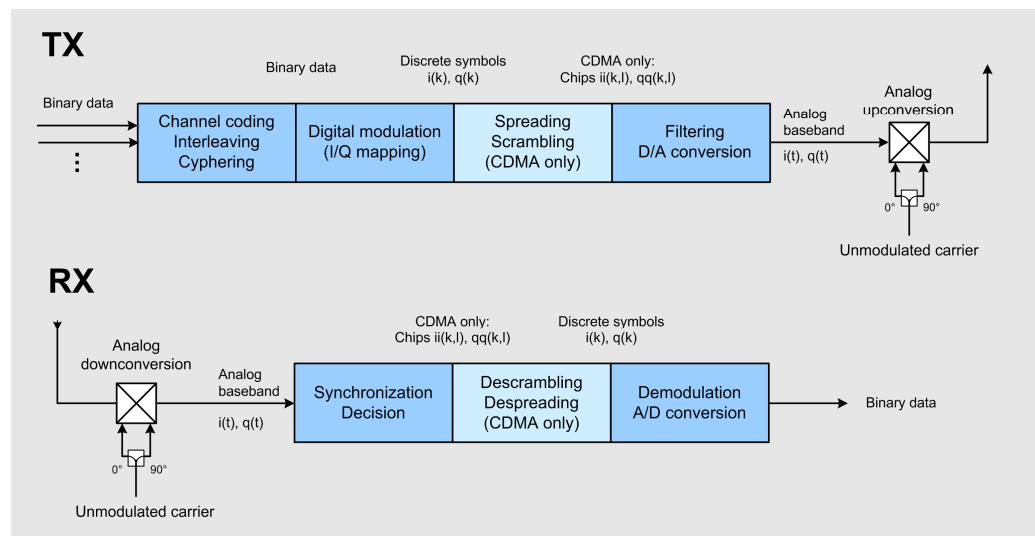
Fig. 2-14: The mobile radio transmission chain.

Starting at the TX side, the binary source data first undergoes channel coding (first block top left in Fig. 2-14). Here, redundancy information is added that can later be used to detect and in some cases correct transmission errors.

The individual wireless communications standards use different methods, including block codes, fire codes, block convolutional codes, turbo codes and so on. There is often a combination of modulation and coding schemes (MCS) based on the required throughput.

Channel coding increases the data volume (more gross data at the same volume of net data). This is followed by interleaving[3]. In the same block, the data might also be encrypted (cyphering). None of these processing steps affects the shape of the later RF signal, the modulation or the required measurements.

The data streams in this first block are binary.

In the case of GSM, the various types of source data from a wireless subscriber (voice data, user data and signaling information) is combined into a binary data stream by means of time division multiplexing.

3GPP UMTS does not make a fundamental distinction between voice and data. The method used to prepare the source data will depend on the data rate. The uplink and

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[3] Modifying the bit sequence so that sequential bits are not transmitted sequentially. This means that time-limited interference will not affect contiguous information, but rather will be distributed over a larger area than a single-bit error. This can be corrected in some cases by available redundancy information.

downlink differ. However, the schematic drawing in Fig. 2-14 is sufficient for a basic understanding.

From received bits the modulation block generates the symbols (I/Q mapping). The binary data is converted to discrete-time I/Q pairs i(k) and q(k), the symbols. These are to be viewed as analog values (for example, think of the I/Q coordinates for 16-QAM). (However, the processing is digital, just as it is in the next two blocks.)

For 3GPP UMTS (or, more precisely, for the code division multiple access (CDMA) method used in 3GPP UMTS), the I/Q coordinates of the symbols are now spread and scrambled.

It is important to note that for 3GPP UMTS the spread I/Q coordinates of all current subscribers are mathematically **added**. The sum signal therefore allocates a much larger value range than the coordinates of the individual vectors, and peak values are more than 10 dB over the average value.

The next block contains a (purely digital) filter, followed by the conversion of the digital values into analog signals. Now, the previous time-discrete values become the continuous analog baseband signals i(t) and q(t). These signals are phase-shifted by 90° and upconverted to the transmit frequency. The sum is the TX transmit signal.

At the receiver end, a downconversion of the input signal to 0 Hz with two 90°-shifted carriers generates two analog baseband signals i(t) and q(t). The receiver synchronizes itself and acquires the I/Q symbols at precisely the symbol points in time (decision). Signal processing is once again digital.

In the case of 3GPP UMTS, the descrambling and despreading occurs at this point. This means that the symbols with the unspread coordinates are retrieved from the spread coordinates. This stage is not present for GSM.

During the subsequent demodulation (demapping), the analog coordinates i(k), q(k) of the symbols provide the bits, i.e. the binary data.

Note: Multifrequency systems and multiple antenna systems require more effort than the scenario shown in Fig. 2-14 on page 16, but the basic steps remain the same.

Duplex operation and multiple access

A radio link between the base station and the mobile station is typically set up in both directions, i.e. in full duplex mode.

However, if the uplink and downlink[4] use different frequencies, this is called frequency division duplex (**FDD**). The standards define a fixed frequency spacing (duplex

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[4] Uplink, UL, also called reverse link: Radio link from the mobile station to the base station. Downlink, DL, also called forward link: Radio link from the base station to the mobile station.

spacing) between the uplink and downlink, e.g. 45 MHz for 900 MHz GSM. This means that the uplink and downlink channels always use the same bandwidth. FDD is easy to implement.

If the uplink and downlink use the same frequency in alternating time periods[5], this is called time division duplex (**TDD**). This mode is more efficient when different data rates are used for the transport in the uplink and the downlink.

In TDD, a mobile station does not need to transmit and receive at the same time. A duplex filter is therefore not needed for decoupling the TX and RX. However, a time synchronization between the BS and MS is needed, and guard periods must be added so that signals received at the base stations never overlap in spite of the varying signal delays from the individual subscribers resulting from their different distance from the BS.

The GSM standard and the 3GPP UMTS standard, which is in wide use both inside and outside of Europe, both use frequency division duplex. (China also uses a 3GPP UMTS TDD variant called TD-SCDMA.)

True duplex operation is generally required only for voice connections. Data connections are often one-sided (e.g. upload, download, streaming) or asymmetrical with respect to the data rate. For these, a packet-oriented traffic is often more suitable.

2.2 Access Methods

Digital wireless communications networks are organized into cells. Because radio waves have a limited range, it is possible to define an area – called a cell – inside of which service to wireless subscribers is provided by one single base station (BS). At the reception boundaries, a mobile phone (also called a mobile station, MS or user equipment, UE) is automatically switched to the adjacent cell that is most suitable (handover). This typically also involves a change in frequency. The original frequency might then be available again in the next cell over (frequency reuse).

Because every cell is limited to a specific area, it has to handle a finite number of wireless subscribers. Or, stated conversely: The size of a wireless communications cell is determined primarily by its required capacity. Because the available resources of frequency, time and – as we will see later – code are limited, locations with a large potential number of subscribers must have many base stations with low power. Regions with fewer subscribers can have large cells with high power base stations. The point is to ensure that multiple subscribers have access to a fixed percentage of the resources frequency, time and code – independent of the uplink / downlink duplex.

Three different methods are used most frequently:

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[5] Voice data is collected in segments so that it can then be transmitted in the available shorter time windows, with a corresponding increase in speed. At the receive end, the segments are "expanded" again to give the impression of a continuous connection.

▪ Frequency division multiple access (FDMA),

▪ Time division multiple access (TDMA) and

▪ Code division multiple access (CDMA).

Fig. 2-15 illustrates the differences. This simplification assumes only five subscribers (each represented by a different color), all with equal power. This is seldom the case in practice, but it is sufficient for understanding the differences.
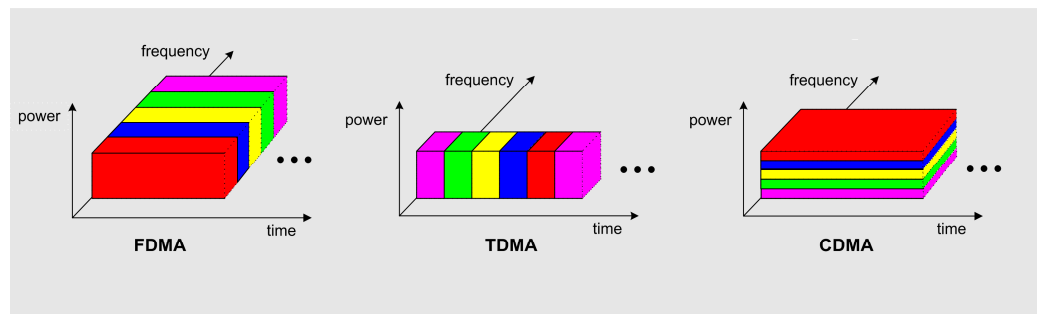
Fig. 2-15: Three important access methods.

FDMA distributes the wireless subscribers in a cell among different frequencies. Fig. 2-15 shows five subscribers allocated to five frequencies. For FDD, this means five frequency pairs. FDMA is very easy to implement. This method is particularly useful in small cells where the allocated frequencies can be reused a short distance away. FDMA is often used in combination with TDD, e.g. for DECT[6] and WLAN[7] (both standards specialize in connections over short distances).

TDMA distributes the subscribers sequentially into timeslots. The bursts from each subscriber in a TDMA frame must fit exactly into the time slots at the receiver input on the base station. Because of the varying distances, the timing of individual MS transmit signals will therefore need to be fine-tuned based on their specific signal propagation time.

GSM uses eight slots in its TDMA frame and opens by this eight radio channels. To cover the much greater demand for radio channels, each GSM cell "owns" a set of many frequencies (uplink / downlink frequency pairs).

CDMA individually codes the symbols of the various subscribers in a cell. This method is suitable for both FDD and TDD. 3GPP-WCDMA works together with FDD, i.e. all connections continuously use one common uplink frequency and one common downlink frequency. The TD-SCDMA introduced in China uses TDD. The uplink and

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[6] Digital enhanced cordless telecommunications

[7] Wireless local area network

downlink of a cell there use one and the same frequency for all subscribers. Up- and downlink use time division multiplexing, and all cells use a uniform time grid.

CDMA is very flexible. It is primarily suited for operating many channels simultaneously at different data rates. However, it requires a sophisticated management of the various transmit powers and much greater processing performance than e.g. GSM. This increases the energy consumption of the mobile stations and reduces the maximum operating time per battery charge.

3 Wireless Communications Measurements: Motivation and Structure

A modern wireless communications system shall ensure that each authorized subscriber can place a phone call from anywhere and at any time without problems. The data transfer must also function everywhere reliably and without interference.

While this requires a good network infrastructure[8], it is also imperative that the base station and mobile station characteristics meet exact requirements.

▪ All transceivers must meet certain minimum requirements in order to communicate in the network. This includes completely error-free handling of communications protocols (connection setup, clear down, etc.), but also other requirements such as a minimum RF output power and sufficient receiver sensitivity. For universal usage – even in the vicinity of electrical machines, for example – resistance to EMI and external fields is extremely important.

▪ Each device must also meet specific tolerances in order to communicate with devices from other manufacturers (interoperability). For example, TDMA systems have a tolerance mask for burst timing. If this mask is not adhered to, the transmit signals from various subscribers will overlap and network operation will be significantly degrade.

▪ A transceiver must also not interfere with other devices or services. This requires adherence to limit values and tolerances for RF leakage into the own and other frequency bands.

All of these requirements are specified in the respective wireless communications standards. The standards precisely define what must be measured so that a new base station or mobile station can obtain the legally mandated type approval. They include not only the required tests, but also how these tests are to be performed and which reference and limit values apply. They additionally define "normal" and "extreme" operating conditions under which the specified tolerances must be satisfied.

The type approval tests are typically performed by independent, certified test houses. (Most of these use test systems from Rohde & Schwarz.)

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[8] Coverage measurements are indispensible when implementing and optimizing the network infrastructure. Test vehicles explore the region and document the quality of the received base station signals. Coverage gaps and areas with conditions that make reception more difficult are identified. This makes it possible to define infrastructure changes to improve the situation. (Coverage measurements are not discussed in this application note.)

All of the tests described in the respective standards must be passed by each mobile phone type, without exception, during type approval. This involves several hours of test time for a DUT. However, once type approval is obtained for a model, it is no longer necessary to do each test from the standard on each individual device (e.g. during production). Certain firmware-based features, such as protocol management, are the same for all devices in a series. Because all telephones in a series are built in the same way using the same hardware, it is sufficient to perform other tests on random samples. The same applies for spectrum measurements.

Tests on mobile stations can be categorized using several different criteria. One possibility is shown in Fig. 3-1:
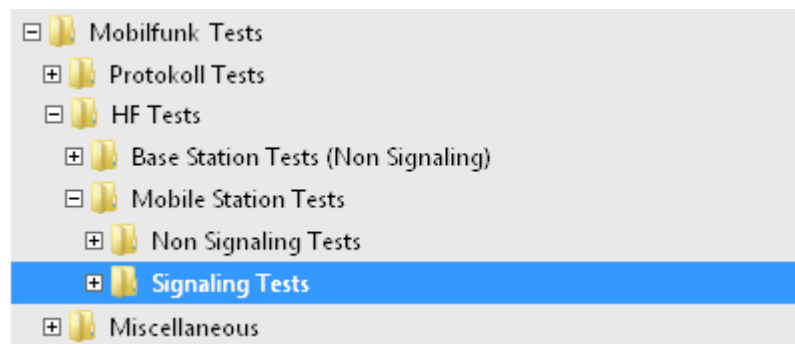
Fig. 3-1: Classification of wireless communications tests.

In this case, the initial distinction is made between protocol tests and RF tests.

The protocol sequences are implemented as software. Once these have been successfully completed for a base station or mobile station type, they no longer need to be tested on other devices of the same type.

In this application note, RF tests are covered. *Tests* involve a check of physical characteristics; in order words, measurements and evaluation of the results.

The RF tests can be further categorized into base station tests (BS tests) and mobile station tests (MS tests).

Both categories include approximately the same type of tests, but with different reference and limit values and tolerances. One main difference lies in the fact that the BS tests are performed almost exclusively in non-signaling mode.

Mobile stations and components are also calibrated in non-signaling mode during production. During the functional tests in production, during conformance and precompliance tests[9] and during service, however, the tests are mostly run in signaling mode.

The practical portion of this application note covers signaling tests only.

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[9] Precompliance tests are tests performed by a manufacturer to ascertain in advance whether a model meets the requirements for the type approval (conformance) tests.

Signaling mode

The device under test (DUT) establishes a radio link with the tester, as for a telephone call, and is then controlled via the air interface.

The MS and tester are "RF coupled", either via a cable or antenna (in a shielded chamber). The tester simulates a base station.

In the MS, a special test SIM ensures that the DUT registers only with the tester, not in a public network. (In GSM, the test SIM also makes it possible to close an internal loop between the RX and TX paths for bit error measurements.) A connection is then set up between the DUT and the test equipment (tester), initiated either by the tester or by the mobile phone.

At this point, the testing can start. For example, the tester signals over the air interface that the DUT should transmit on a specific frequency and at a specific power level. Measurements are now taken of the frequency accuracy and the transmit power (typical TX tests). Or, the tester can instruct the DUT to establish an internal loop from RX to TX in order to measure bit error rates (typical RX test).

The tester always controls the activities.

The commands and protocols for controlling the DUT are defined in the standards and therefore apply to all DUTs. This means that every tester has the ability to control mobile stations from all manufacturers, in the same way. This is a big advantage.

Non-signaling mode

Unfortunately, signaling tests can be performed only on mobile stations that already have most of their final functionality, i.e. they have been calibrated and have functioning firmware. In addition, connection setup uses valuable test time.

In the earlier phases of MS production, e.g. when calibrating individual components, the air interface is not yet functional and signaling is not possible. This means that calibration procedures during production are always performed without signaling and the DUT is controlled by means of proprietary interfaces. Proprietary applications are also used to control the test equipment and the tester plays a secondary role.

A disadvantage to non-signaling mode is that DUTs from different manufacturers must be handled individually and there is no uniform process to follow.

A simplified example of calibration in non-signaling mode is the automatic gain control (AGC) calibration:

1. Apply a specific RF level at the RX input of the DUT
2. Calibrate the AGC and buffer the correction value
3. Apply a different RF level, e.g. a lower level
4. Calibrate the AGC and buffer the correction value
5. Repeat steps 3 and 4.

Finally: Save the obtained correction values in non-volatile memory in the DUT.

The CMW500 wideband radiocommunication tester used in the practical portion of this application note can operate in either signaling or non-signaling mode [6]. In a single unit, it unifies the functionality of a base station and the functionality of a mobile radio generator and analyzer.

Through close cooperation with various mobile phone manufacturers, it was possible to add certain test sequences in their entirety to the tester firmware as lists in non-signaling mode.

4 The GSM Standard

The Groupe Spécial Mobile, an association within the CEPT[10] defined the Global System for Mobile Communication (GSM) in Europe in the 1990s. The digital GSM standard brought an abrupt end to the first, analog generation of wireless communications. Beyond the technical advantages afforded by the new system, its spectacular success was based primarily on the fact that handy, affordable cellphones were available shortly thereafter. Mobile calling was no longer an expensive proposition tethered to motor vehicles. Networks expanded quickly; it was suddenly possible to reach people just about anywhere and to place calls from just about anywhere as easily as over a landline. From that point on, cellphones were an essential accessory, on par with keys and briefcases.

For the GSM measurements covered in this application note, the primary focus is on the signal that is transmitted over the air interface, called the physical layer[11]. This requires an understanding of the most important physical characteristics of the GSM system.

Frequency bands	11 bands from 450 MHz to 1900 MHz
Channel grid	200 kHz
Duplex mode	FDD
Multiple access	TDMA
Modulation	GMSK, 8-PSK (16-QAM, 32-QAM)
Filters	Gaussian, enhanced Gaussian
Symbol rate	270.833 kSym/s

Table 4-1: GSM system parameters.

GSM is an FDD system. It has an uplink and a downlink frequency band. For the bands around 900 MHz (for GSM900) or around 1800 MHz (for GSM1800), used primarily in Germany, the spacing between each uplink and downlink channel is 45 MHz or 95 MHz (duplex spacing).

To avoid having to name each set of two frequencies, channel numbers are used that are always the same for an uplink / downlink pair. For example, Channel 62 corresponds to an uplink frequency of 902.4 MHz and a downlink frequency of 947.2 MHz. (Channel 62 is the default setting for the CMW.)

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[10] Conférence Européenne des Administrations des Postes et des Télécommunications

[11] Layer 1 in the ISO model.

GSM uses the Gaussian filtered minimum shift keying (GMSK) method for (*voice*) traffic and slow (*data*) traffic. It represents an optimized form of phase modulation. The level of the modulated signal remains constant. A symbol is made up of one bit. The two possible logical states are realized by means of phase shifts of + 90° or –90°. Unchanging bits on the physical layer result in a continuous phase shift of +90° per symbol duration, while a permanent bit change leads to a continuous phase shift of – 90° per symbol duration. In the spectrum, this results in a frequency shift of +/– 67.7 kHz, which is one quarter of the symbol frequency.

For data with a higher throughput, 8-PSK modulation is used almost exclusively. A symbol is now made up of three bits, thus tripling the data rate. Strong filtering makes it possible to maintain the channel spacing. (More about data transmission later in this application note.)

Channels, frames and slots

Each base station maintains one physical channel (one uplink/downlink frequency pair) for general broadcasting and control purposes that is used in common for all subscribers in the cell. This is called the broadcast channel (**BCCH**) and is used to make general cell information and synchronization signals available. The broadcast channel – via other linked logical channels – is also used to register mobile phones in the cell and to set up and clear down subscriber connections.

After the initial dialog over the BCCH, a base station assigns an available traffic channel to each individual mobile station. The subscriber-specific traffic occurs over this channel. The traffic channel for *voice* is the **TCH** and for *(packet) data* it is the **PDCH**. The later measurement discussions will be focused on these two channels.

These channels are logical channels. However, the measurements are of physical characteristics. The RF signal is therefore analyzed at the specific channel frequency and within the specific time window created for a specific traffic channel.

Note

GSM does not permit a direct connection between two mobile stations. Each mobile connection must route through the base station of the current cell. The traffic to the mobile phone takes place over the base station's downlink signal and the traffic from the mobile station is over the uplink signal. The base station makes the connection to the fixed network and to other mobile radio cells.

Frames and slots

GSM operates in the BCCH and in the TCH / PDCH using a time grid made up of **TDMA frames**. Each TDMA frame consists of eight time **slots**). A slot equals approximately 577 µs (to be exact, 7500/13 µs), and a frame is about 4.62 ms.

Normally, each wireless subscriber is assigned one slot per frame. (It is also possible to allocate multiple slots to improve the data throughput.)

Typically, one TCH frame thus opens eight radio channels. To cover the much greater demand for channels, each GSM cell works with a set of frequencies pairs. For example, there are 124 channel frequencies for GSM900.

Downlink and uplink frames are offset by three slots. This prevents mobile phones from having to transmit and receive at the same time.
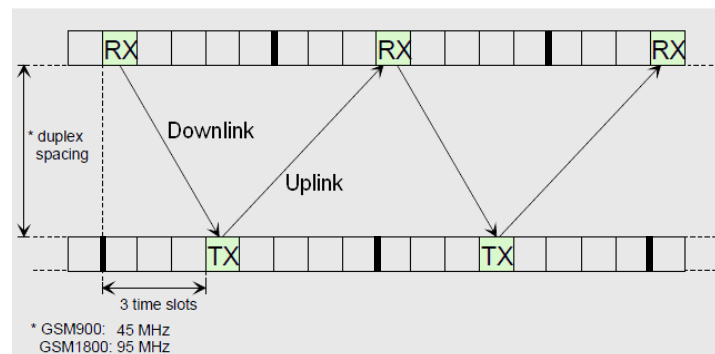

Fig. 4-1: The mobile phone transmits in the 3rd slot after the uplink.

A (full rate) subscriber channel, called a physical channel, is defined by a channel number (a frequency pair) and a timeslot number.

This applies for the *circuit-switched (CS) mode*. A channel is reserved for a connection in every frame. Today, CS mode is used exclusively for voice connections.

For pure data transmission, the *packet-switched (PS) mode* is used. It also allocates one or more slots, but not in each frame. In this case, information about which frame is allocated is required to identify the physical channel.

Supplemental information

In the BCCH, 51 frames are combined into a BCCH multiframe.

In the TCH, 26 frames form a multiframe; frame 12 is reserved for signaling and frame 25 is idle.

In the PDCH, a multiframe consists of 52 frames. Frame 12 and frame 38 can be used for signaling, and frames 25 and 51 are idle.

51 * 26 TDMA frames = 1326 frames form a superframe. This has a duration of approximately 6.12 s and synchronizes the BCCH and TCH.

2048 superframes form a hyperframe. Frames are therefore sequentially numbered from frame number 0 to 2715647 (= 51 * 26 * 2048 − 1).

4.1 The Normal Burst

The TDMA RF signal within a slot is called a burst. The measurements in this application note focus exclusively on the traffic channels TCH and PDCH. The normal burst (NB) format is used. The structure of the normal burst is the same in the uplink and downlink.

Fig. 4-2 shows the shape of the RF signal for a normal burst in the TCH (voice, GMSK modulation).
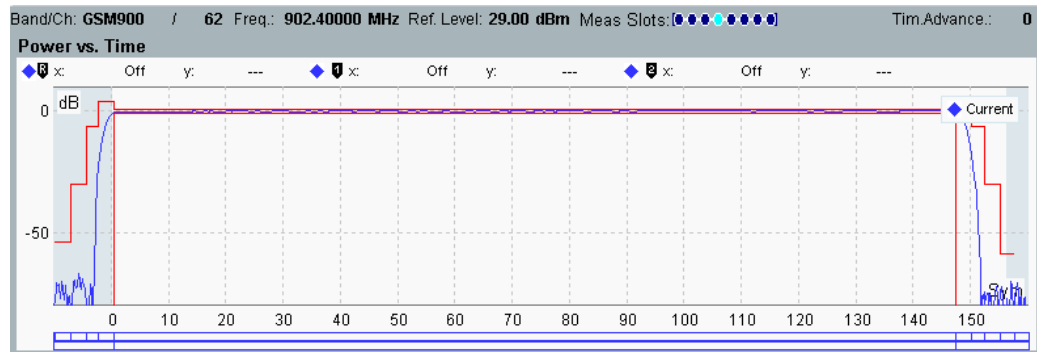

Fig. 4-2: GSM power versus time (GMSK).

To keep from interfering with other TDMA subscribers, the burst must fit into a precisely defined tolerance template (marked in red in Fig. 4-2). The useful part of the burst begins after the rising edge. This area contains the "useful modulation". Because GMSK is used, there will ideally be no power variation here. The RF power drops back off at the end of the useful part.

On the one hand, the burst edges should be as steep as possible to prevent degradation of adjacent slots. On the other hand, an attempt should be made to achieve the most gradual rise and fall possible within the specified tolerances in order to minimize the unwanted spectral components that are generated by the pulsing.

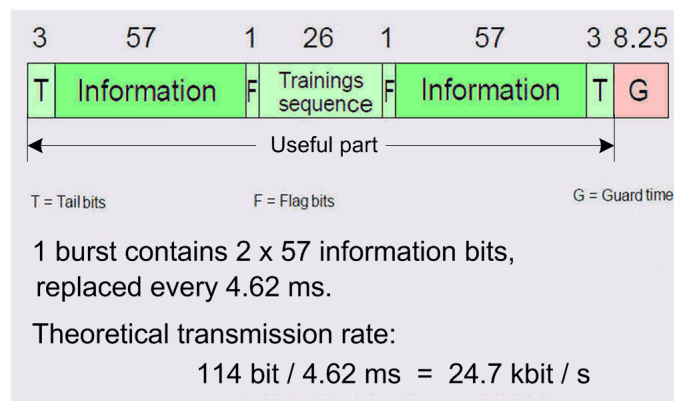Fig. 4-3 shows the internal structure of the normal burst.

Fig. 4-3: Structure of the normal burst (top row: Number of bits).

The width of a slot is about 577 μs, corresponding to 156.25 bits. Of that, the useful part of a burst occupies 148 bits (3 + 57 + 1 + 26 + 1 + 57 + 3). The remaining 8.25 bits form a guard time, during which the power of the current burst must decrease and the power for the next burst can increase.

Voice or data bits are contained in the two information blocks. At one burst per frame, it is possible to achieve a theoretical transmission rate of 24.7 kbit/s.

The training sequence (TSC) in the middle of the burst consists of a fixed bit sequence (for the TCH). It has two functions: On the one hand, it is used to allow the receiver software to synchronize down to the bit. On the other hand, the receiver can use the known TSC bits to parameterize its equalizer filter optimally, and thus partially compensate for signal degradations resulting from the transmission path. The position in the middle of the burst is a good compromise as the propagation conditions may change during the slot duration.

Two flag bits F, also called stealing bits, flank the midamble. If these flag bits are set to "0", then the slot has been "stolen" by the system in order to transmit urgent signaling on an ad hoc basis.

Special characteristics of the TCH normal burst (voice, GMSK)

If the flag bits are set, the traffic channel *TCH* is (for 4 frames) converted into the fast associated control channel *FACCH*. This is necessary during a handover[12], for example.

Special bursts are found in frame 12 and frame 25 of a 26-frame multiframe, see Fig. 4-4.
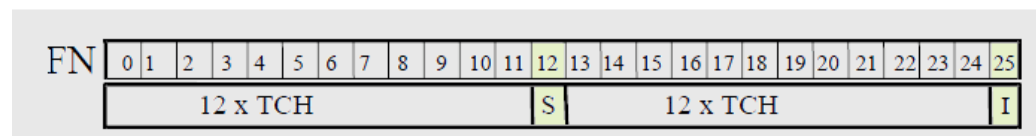
Fig. 4-4: GSM signaling frame (S) for SACCH and idle frame (I).

In frame 12, the traffic channel *TCH* is replaced by the slow associated control channel *SACCH*. Compared with the FACCH, the SACCH has slow but regular signaling. One task of the SACCH is to control the transmit power of the mobile phone.

In contrast to general signaling in the BCCH control channel, the two control channels FACCH (fast, temporary) and SACCH (slow, regular) are each associated with a specific subscriber.

Frame 25 is the idle frame, which is not used for transmission. The mobile station uses the idle time to scan for base stations other than the current one. The quality of the reception is then used to determine whether it makes sense to hand over the call to a different base station / cell.

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[12] Reconfiguring the connection to a different frequency within the same cell, or transfer to a different cell.

After accounting for the SACCH and the idle frame, the gross bit rate for GMSK modulation is only 22.8 kbit/s (instead of the theoretical rate of 24.7 kbit/s).

Special characteristics of the PDCH normal burst (packet data)

The structure of the normal burst as shown in Fig. 4-3 on page 28 applies to voice and data bursts using GMSK modulation as well as to data bursts using 8-PSK modulation. In this case, however, the term "bit" is replaced by the term "symbol".

There is a change in the power versus time:
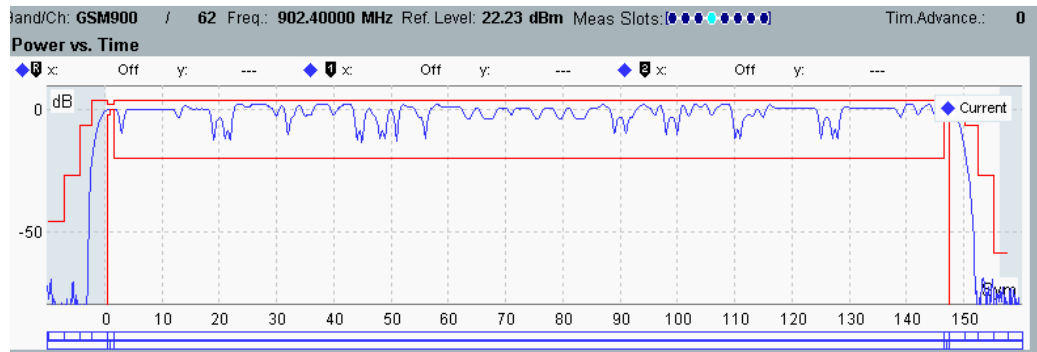
Fig. 4-5: GSM power versus time (8-PSK).

An 8-PSK signal has power peaks and troughs. Taking this into account the power template specified in the standard is extended. The transmit stages in the BS and MS require a higher degree of linearity in order to transmit the signal without distortion.

Packet data is "quantized" into radio blocks. These blocks comprise the contents of four frames (at 1 slot per frame). A 52-frame multiframe contains 12 radio blocks, B1 to B11, see Fig. 4-6.

Fig. 4-6: GSM idle (I) and possible signaling frames (S) for PS connections.

A signaling frame (S) can be active in frames 12 and 38. It is the packet timing control channel PTCCH which controls the timing of the uplink signal (Timing Advance, see page **Fehler! Textmarke nicht definiert.**). Frames 25 and 51 are always idle (I).

4.2 Circuit-Switched and Packet-Switched Modes

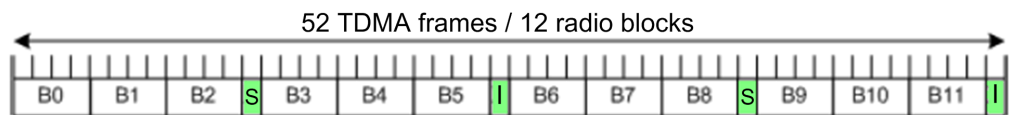In this application note, GSM measurements are performed in circuit-switched mode as well as in packet-switched mode. (On the CMW, the choice between these two is made during call setup by selecting either *CS Connect* or *PS Connect*.)

A continuous connection is considered to be ***circuit-switched*** (CS). In wireless communications, this mode is now used only for voice transmission. A form of CS data transmission (HSCSD high speed circuit switched data) originally planned for GSM is no longer used. After a circuit-switched connection is set up, the status is ***call established***.

A ***packet-switched*** (PS) connection is one in which not <u>every</u> TDMA frame is permanently allocated (i.e. not one or more slots are permanently allocated in every TDMA frame). In GSM, PS is used for data traffic. Different data rates are possible in the uplink and downlink: It is possible for different modulation and coding schemes and differing numbers of slots to be used in the two directions. When a packet-switched connection has been set up, the status is ***TBF established*** (temporary block flow established).

Modulation and coding schemes for packet-switched data

The introduction of higher data rates in GSM packet service was accomplished over several steps.

Table 4-2 on page 31 compares these *TBF levels*.

◻   **GPRS** (General Packet Radio Service),

◻   **EGPRS / EDGE** (Enhanced Data for GSM Evolution) and

◻   **EGPRS2-A** / EDGE Evolution).

Packet Radio Services		
TBF Levels	**Modulation**	**Modulation and Coding Scheme**
GPRS	GMSK	CS-1 ... CS-4
EGPRS / EDGE	GMSK	MCS-1 ... MCS-4
	8-PSK	MCS-5 ... MCS-9
EGPRS2-A	16-QAM	UAS-7 ... UAS-11 in the uplink
	32-QAM	(downlink only)

Table 4-2: GSM packet radio services (TBF levels).

Different combinations of modulation and coding are specified for the individual levels. They are called coding schemes (CS) and modulation and coding schemes (MCS).

GPRS initially offered a maximum data rate of 14.4 kbit/s. User data was modulated as GMSK speech data. There were four coding schemes (CS1 to CS4) with different levels of transmission protection.

EDGE defined both **EGPRS** (enhanced general packet radio service) as well as packet-switched and ECSD (enhanced circuit switched data) as a circuit-switched data service. The latter was not sustainable, and as a result EDGE is now comparable to EGPRS and is used as a synonym for packet-oriented fast data service in GSM. The new schemes MCS-1 to MCS-9, and in particular the 8-PSK modulation mode, made it possible to significantly increase the data throughput, see Table 4-3.

MCS	Data Rate (kbit/s per Slot)	Modulation
EGPRS / EDGE Data Rates		
MCS-1	8.8	GMSK
MCS-2	11.2	GMSK
MCS-3	14.8	GMSK
MCS-4	17.6	GMSK
MCS-5	22.4	8-PSK
MCS-6	29.6	8-PSK
MCS-7	44.8	8-PSK
MCS-8	54.4	8-PSK
MCS-9	59.2	8-PSK

Table 4-3: MCS-1 – MCS-9 / data rates and modulation.

Combining eight timeslots for a subscriber in MCS-9 results in a theoretical data rate of 473.6 kbit/s. However, in actual mobile phones (multi-slot class 10), only a maximum of four downlink slots and two uplink slots are used. With MCS-8, maximum data transmission rates of around 220 kbit/s in the downlink and 110 kbit/s in the uplink are possible.

EGPRS2-A (EDGE evolution) also used modulation modes 16-QAM and 32-QAM to further improve the data throughput. This was possible by means of a simple software update on some mobile phones. When combined with a turbo-coder, it was possible to achieve transmission rates of up to 1 Mbit/s.

However, EGPRS2-A quickly came under strong competition from 3GPP UMTS with its superior high-speed channels. 16-QAM and 32-QAM modulations therefore never came into broad usage, and EDGE was not development further.

Note

Modulation and coding schemes for higher data rates contain less redundancy information. This decreases the robustness of the radio link against interference. The MCSs available for use therefore depend on the quality of the radio channel (and of course on which modulation and coding schemes are supported by the BS and MS).

Timing advance

To prevent mutual interference, the TX bursts from all mobile stations must arrive at the RX antenna of a base station in a precise TDMA slot grid. Because of the varying distances between the individual mobile stations and the base station, the signal propagation times will result in different signal delays. Fig. 4-7 shows an example.
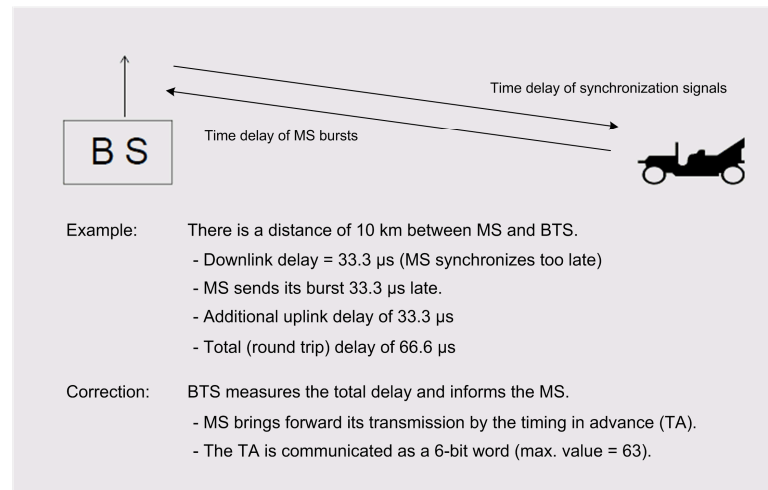
Fig. 4-7: Example of signal delay resulting from travel time.

Because the mobile station first synchronizes with the downlink signal, which also requires propagation time, the delays will apply to both paths, i.e. to and from the mobile station, resulting in double the single delay.

At the GSM symbol rate of 270.833 kHz, the duration of a bit is 3.69 µs. The 66.6 µs shown in the example corresponds to a delay of about 18 bits, in other words a lag in the slot grid of more than 10 %.

This has to be be compensated. The base station therefore requests each individual subscriber to transmit in advance. This timing in advance (TA) is transmitted over the fast signaling channel, FACCH.

4.3 Measurements on GSM Mobile Stations

Nearly all measurements required for GSM mobile stations are based on the ETSI specification TS 51.010-1. The tests included in this specification are mandatory for the approval of any new model of mobile phone. They define the reference characteristics and the permissible tolerances for mobile phone production as well as for service.

The following overview focuses on the essential RF tests. The first four are covered in detail starting in chapter 8 of this application note and are performed using the CMS radio communication tester.

A distinction is made between TX and RX measurements.

The most important topics for the TX measurements are

- Transmitter output power

  This measurement covers the absolute burst power at the individual power control levels, plus the burst timing.

- Modulation quality

  This measurement includes phase and frequency error, magnitude error and error vector magnitude. The CMW can also be used to determine the I/Q imbalance and the I/Q offset.

- Output RF spectrum

  GSM distinguishes between the emissions caused by modulation (spectrum due to modulation, or DTM) and the emissions resulting from burst edges (spectrum due to switching, or DTS). Measurements are performed at discrete frequencies only.

RX measurements are primarily concerned with determining the receiver sensitivity under normal and extreme conditions. This is always accomplished indirectly, using measurements of the bit and block error rates or the achievable throughput.

The most important topics for the RX measurements are

- RX sensitivity
- Blocking measurements
- Co- / adjacent channel, intermodulation rejection

For the *blocking* and *interferer rejection* measurements, the test setup must include some instrumentation beyond the CMW, such as generators. This application note does not cover these tests.

5 Sequence of Wireless Communications Measurements

In signaling mode measurements, the mobile station (the DUT) is operated precisely as it is expected to function later during network operation: After being switched on, a mobile phone must search for a base station (cell), to which it synchronizes and registers. The base station is represented by the CMW. Only afterwards can the phone make a call (set up a connection) or receive a call. Once a call ends, another call can be made. If synchronization with the base station is lost, it might be necessary to switch the mobile station off and on again to resynchronize quickly. (This is because the search for a base station starts at the frequency of the last cell used.)

The CMW uses a *measurement task* to perform the measurement. Fig. 5-1 shows how the measurements are embedded in the yellow range where the cell signaling (the CMW *signaling task*) is active. The noted sequences apply equally to GSM and 3GPP WCDMA.

Comment

Signaling and measurement tasks must both be preconfigured!

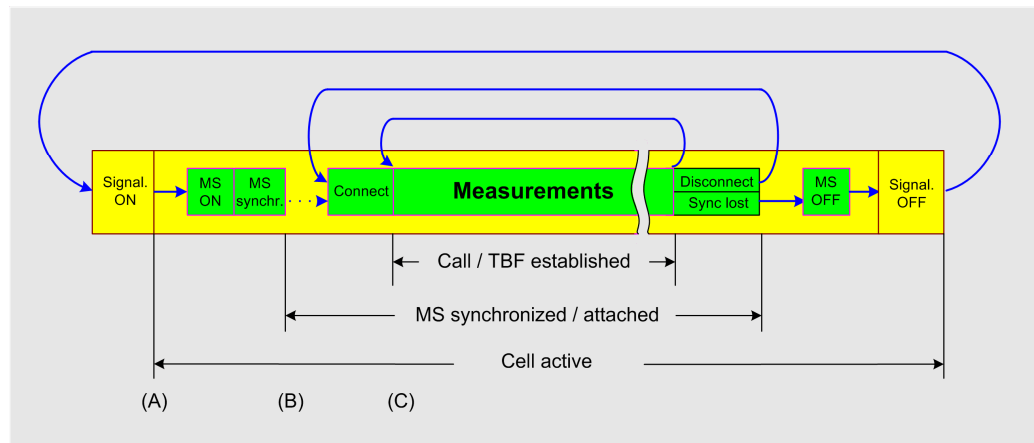Fig. 5-1: Schematic flow of wireless communications measurements.[13]

All measurements therefore follow the same sequence:

1. Configure the signaling task. Start the signaling task (Signaling ON (A)).

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[13]In GSM, "temporary block flow (TBF) established" is the packet-switched equivalent of "call established" for circuit-switched connections. "Attached" is the equivalent of "synchronized".

2. Switch on the DUT (MS ON). The mobile station registers and synchronizes with the test cell generated by the CMW (B).

3. Configure the measurement task.

4. Initiate a call from the DUT or have the CMW place a call (Connect). The radio link is established (Call / TBF Established, (C)).

(If you initiate a CS connection from the CMW (CS Connect), you have to unhook when alerting. Only then is the connection established. In the case of a PS connection, the mobile phone picks up the call automatically.)

5. Start the measurement task(s).

6. Evaluate the measurement results.

If no other measurements will follow, clear down the call (Disconnect) and switch off the DUT (the mobile station) as well as the signaling at the CMW.

If further tests are needed, you must determine which parameters need to be redefined. A different power level or a different modulation and coding scheme (MCS) can be set <u>during an existing call</u>.

7. In this case, configure the task and start the new measurement (step 5).

Many other parameters can be changed only if <u>no</u> voice or data call is set up (MS not connected). This includes the selection of the test loop for GSM (test / service mode selection), for example. The CMW will not allow any changes to this selection during an active call.

8. In this case, you must disconnect. Modify the appropriate parameters in the signaling or the measurement task and set up the call again (step 4).

For many tests, the connection can be lost during the measurement, in which case the synchronization is lost. In RX sensitivity tests, this is typical when the downlink level drops too low. Because only the DUT knows whether it is synchronized, the CMW will continue to display "Synchronized" or "Attached". This means that the MS will be able to resynchronize without registering again.

► If this happens, to be safe you must switch *OFF* the signaling on the CMW (increase the downlink level as needed) and then switch the signaling back *ON*.

► Switch the DUT off and on again as well, wait for the registration to complete and then establish the connection again.

9. After completing all measurement tasks, disconnect the radio connection between the DUT and the CMW (Disconnect), then switch off the MS and switch off the signaling on the CMW.

6 Measurements with the CMW500

The CMW500 wideband radio communication tester is a universal tester for the air interface used by wireless devices and modules. It can be used in all phases of product development and supports all conventional cellular and noncellular technologies. Table 6-1 provides an overview:

Use of the R&S®CMW500 for cellular wireless technologies

Technology	RF generator	RF analyzer	Network emulation	Protocol test	End-to-end application test
LTE FDD	•	•	•	•	•
LTE TDD (TD-LTE)	•	•	•	•	•
Mobile WiMAX™	•	•	•		•
CDMA2000® 1xRTT	•	•	•		•
CDMA2000® 1xEV-DO	•	•	•		•
TD-SCDMA	•	•			
WCDMA/HSPA+	•	•	•	•	•
GSM/GPRS/EDGE/EDGE Evolution	•	•	•	•	•

Use of the R&S®CMW500 for non-cellular wireless technologies

Technology	RF generator	RF analyzer
GPS	•	
Bluetooth®	•	•
WLAN a/b/g/n	•	•

Use of the R&S®CMW500 for broadcast technologies

Technology	RF generator
DVB-T	•
T-DMB	•
MediaFLO™	•
CMMB	•
FM stereo	•

Table 6-1: Application options for the CMW wideband radio communication tester.

The CMW500 is appropriate for the following applications:

▪ Component tests, system and integration tests, regression tests, precompliance tests and production tests

▪ All phases of development, verification and production

▪ All protocol layers, ranging from RF and protocol tests to end-to-end application tests

This application note covers only a small portion of the available functions, i.e. measurements on GSM mobile phones.

Before delving into the "hands-on" exercises, it is important to become more familiar with the test instrument itself. Sections 6.1 and 6.2 of this application note therefore cover the operation of the CMW.

Chapter 7 describes a device configuration that forms the basis for all GSM measurements. Chapter 8 then starts the practical exercises.

Note:

Users should learn to operate the CMW by frequently repeating similar functions (learning by doing). This means that not all functionality of the instrument can be addressed here. Answers to questions can be found in the instrument manual [6]. Context-sensitive help is also available on the instrument itself by using the (yellow) Help hardkey.

It is also highly recommended that you study the *GSM Firmware Applications, User Manual* [7] in advance, and that you have it on hand during the practical exercises. This manual includes an index that can be used to find the most important topics quickly, along with numerous tables, including the radio frequency bands, power classes, device classes and so on.

6.1   Basic Operation of the CMW500

The procedures performed by the CMW radio communication tester are called tasks. These tasks must be

ı   selected / loaded,

ı   configured and then

ı   activated / started.

When a task is selected, the corresponding software is loaded and the task added to a list internal to the CMW. The task then appears in the task softkey bar, for example. However, the task is not yet active.

Each task has its own configuration window that must be completed before the task is started (activated).

A loaded task is activated / started by pressing the *ON/OFF* key on the instrument (hardkey).

The CMW recognizes two types of tasks:

ı   *SIGNALING / GENERATOR*: These tasks are used to provide signaling (and/or a generator signal). Examples are GSM generator, GSM signaling, WCDMA generator, etc.

◾ *MEASURE*: These tasks perform measurements. Examples are GSM multi evaluation, GSM RX measurement, WCDMA TX / RX measurement, LTE extended BLER and many more.

There is a good reason to separate signaling tasks from measurement tasks. The CMW considers measurements independently of signaling mode. This is because in the real world, it does not matter whether the transmission of a DUT, e.g. for a TX measurement, was initiated by means of signaling over the RF or over a proprietary, wired test interface.

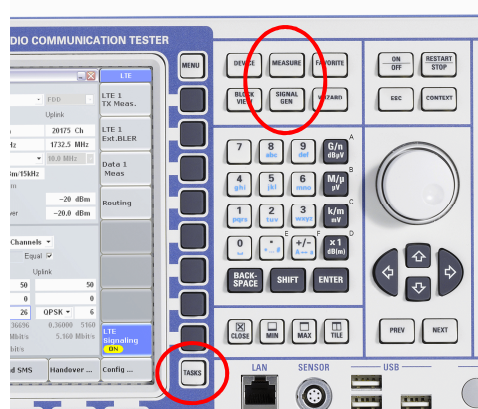The *SIGNAL / GEN* and *MEASURE* hardkeys directly open windows where the necessary tasks can be selected.

Fig. 6-1: Hardkeys for selecting signaling and measurement tasks and for opening the task bar.

Selecting the signaling and measurement tasks

Fig. 6-2 shows the task selection windows opened by the *SIGNAL / GEN* and *MEASURE* hardkeys:
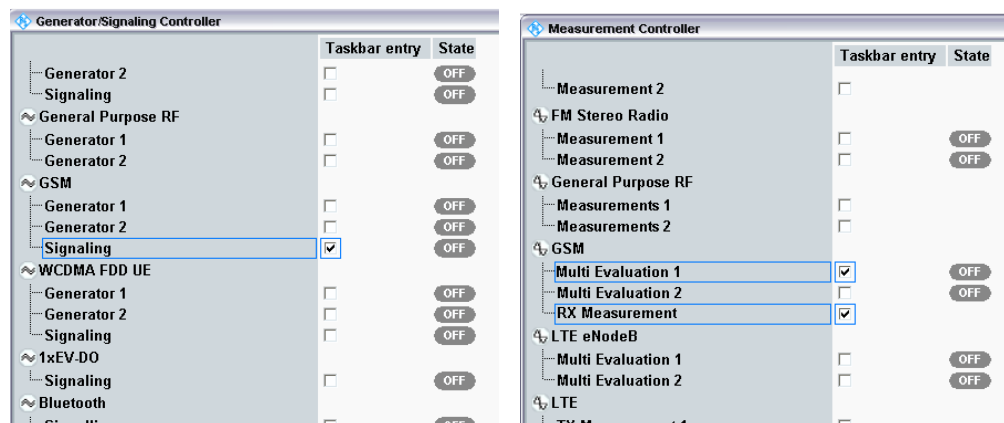

Fig. 6-2: Windows for selecting signaling tasks (left) and measurement tasks (right).

This application note covers only signaling tests. The CMW functions as a base station and controls the DUT via the RF interface. For GSM the GSM signaling task is used.

In Fig. 6-2, this task is selected but not yet active (*State OFF*).

The measurements will use the multi evaluation task (for TX) as well as the RX measurement task. In Fig. 6-2, these two tasks have already been selected, but are not active (*State OFF*). (In the two-channel tester used for Fig. 6-2, there are two GSM multi evaluation tasks, but only one is needed here.)

The *TASKS* hardkey opens a softkey bar that lists all loaded tasks as well as those automatically suggested by the CMW firmware. This softkey bar is used to switch easily between tasks, see also Fig. 6-3.

A task needs to be selected (i.e. loaded) only once for all measurements. However, the task configuration will typically change from one measurement to the next.

Before discussing this configuration, first a few words about the CMW softkey design.

6.2 The Softkey Design on the Tester

CMW operation involves working with tasks. For GSM, this means the signaling task, the multi evaluation task and the RX measurement task.

Tasks can be selected using the task selection bar (opened with the *TASKS* hardkey). Fig. 6-3 shows this bar with the three most important GSM tasks.

Fig. 6-3: The task bar.

The blue color of the softkey to the left in Fig. 6-3 indicates that this task is already selected. In other words, the rest of the content on the screen is already associated with the signaling task.

To switch to a different task, press the (gray) softkey of a task that is not currently selected.

Note: Pressing a blue softkey in the task bar will close that task!

Each task has its own main view, consisting of a unique vertical softkey bar, a unique horizontal softkey bar and various display and configuration windows.

For GSM, we use the three main views of the three mentioned tasks.

The softkey hierarchy was designed to be flat and clear. For tasks, the task level is the highest user interface level. Softkeys and configuration windows open one or at most two sublevels. The *ESC* hardkey closes the currently active window and returns the user to the previous, higher level (until the task level is reached).

Fig. 6-4 shows the main view (task level) and the softkey bars for the GSM signaling task, and Fig. 6-5 shows the main view and the softkey bars for the GSM TX measurement multi evaluation task.
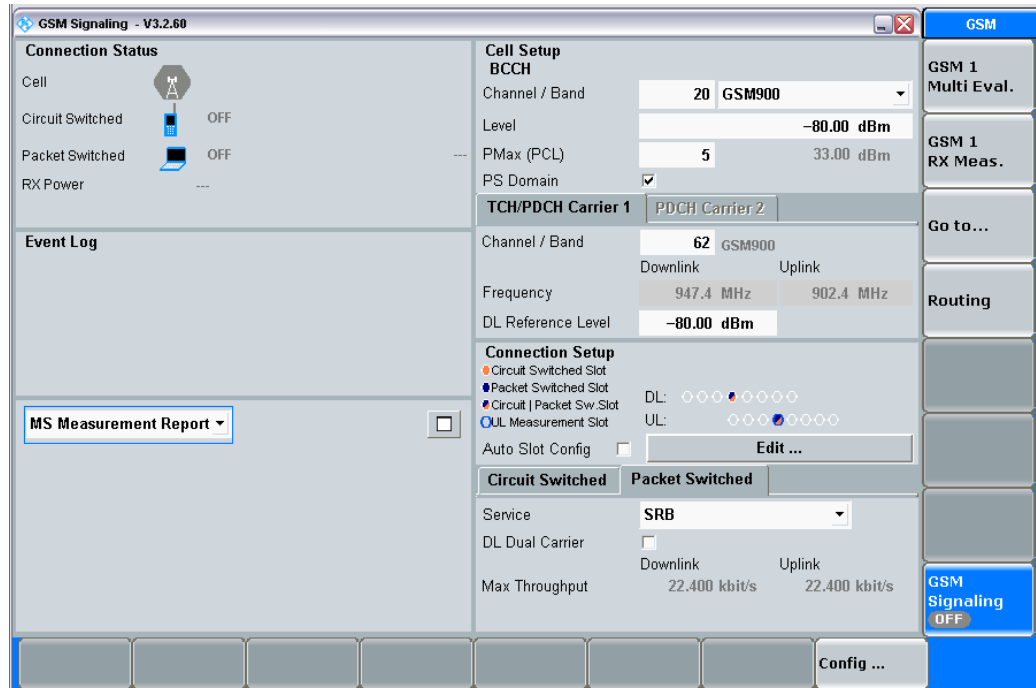
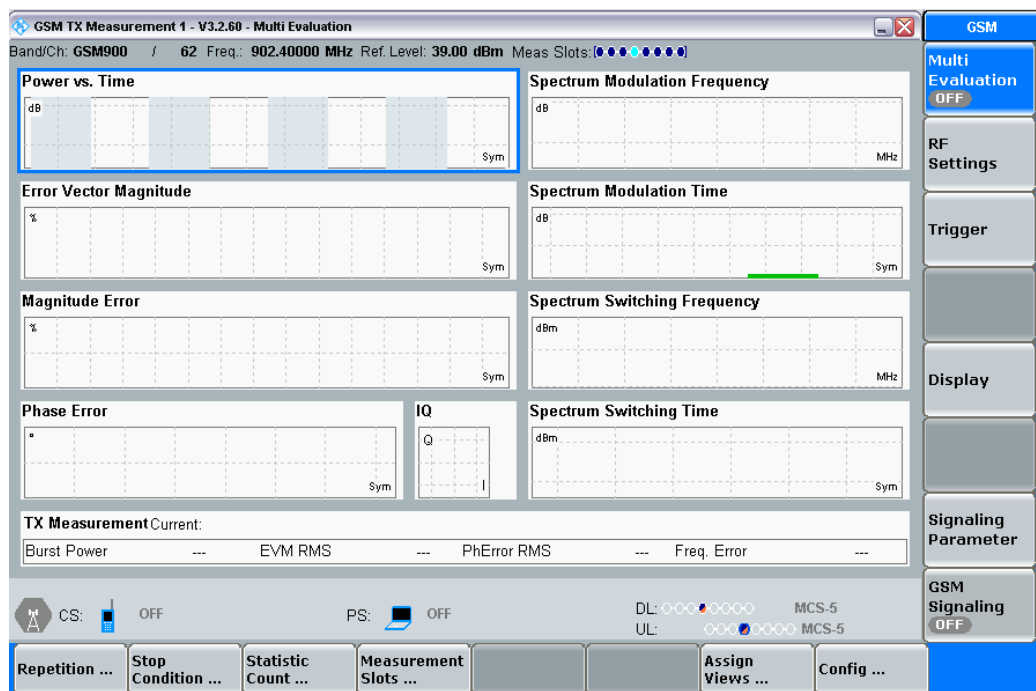**Fig. 6-4: Main view for the GSM signaling task.**

Fig. 6-5: Main view for the GSM TX measurement 1 / multi evaluation task.

In both cases, the task is not yet active and therefore the screen contents are not very informative. The point here is to recognize the vertical and horizontal softkey bars. (In addition to the softkeys, the screen also includes several input fields and edit windows

accessible via the cursor and rotary knobl. These fields and windows will be covered in later chapters.)

Generally speaking, the softkeys in the vertical bar offer a high-level topic selection. They can be considered as a headline for the corresponding horizontal softkey bar. The softkeys there control the operation of the measurement and the evaluation of the results.

When comparing the two main views on page 42, it is important to note the following:

1. Either of the two measurement tasks can be selected from the vertical softkey bar at the right in the signaling task view (Fig. 6-4 on page 42), and the signaling task can be selected from the bar at the right in the multi evaluation task view (as well as the RX task view). This means that the task can be changed at this level as well; it does not have to be changed using the task bar.

   In order to move from the signaling view directly into the main view of a measurement task, press the corresponding measurement task softkey <u>one time</u>.

   To move completely from a measurement view to the signaling view, press the signaling softkey <u>twice</u>. The first press of the softkey will simply change the horizontal softkey bar[14].

2. For each task, the horizontal softkey bar includes the *Config* softkey that is used to configure this task. Of course, the *Config* softkeys for the various tasks open different task-specific configuration windows.

Pressing a softkey in the vertical softkey bar turns that softkey blue. If it is a task softkey, the blue color indicates that the ON / OFF hardkey will activate or deactivate this specific task and that the *Config* softkey will open the configuration window for this specific task.

For example, on the Signaling screen (Fig. 6-4 on page 41), the signaling task is selected (blue softkey in the vertical softkey bar). Use *ON/OFF* to activate the signaling task.

In the Multi Evaluation screen (Fig. 6-5 on page 41), the multi evaluation task is selected (blue softkey in the vertical softkey bar). In this case, use *ON/OFF* to activate the multi evaluation task.

No tasks are switched on (active) in either of the figures. An active task is indicated by a yellow status field on the corresponding softkey, see Fig. 6-6 on page 43.

This figure shows a measurement of a GSM data connection. Two tasks are active, the multi evaluation task is running in the foreground, and the signaling task is running in the background.

The screen and the horizontal softkey bar belong to the multi evaluation task.

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[14] This makes it possible to configure signaling settings quickly without losing track of the measurement task, for example to change the DUT transmit level or the modulation scheme.
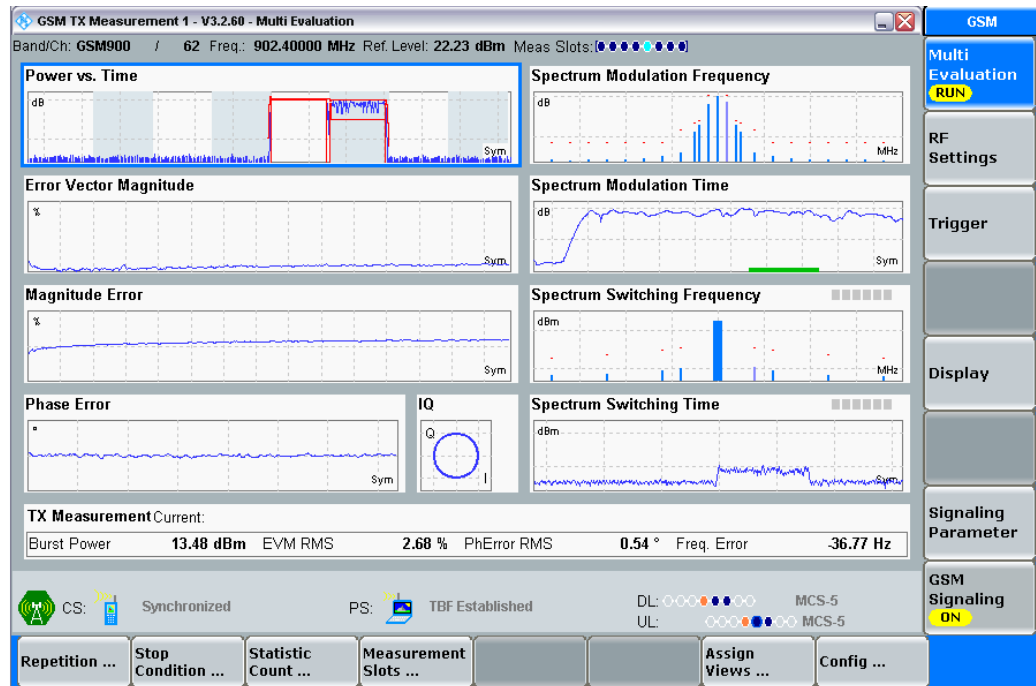
Fig. 6-6: Multi evaluation and signaling tasks are active.

Press the *Signaling* softkey once to open the horizontal softkey bar for the *signaling* task without opening the result display. Press the *Signaling* softkey a second time to switch to the *Signaling* screen with the corresponding softkey bar.

On all screens, the softkeys on the horizontal bar and in some cases configuration windows are used to open deeper user interface levels with drop-down lists or input windows.

For example, the *Repetition* softkey is used to choose between *SingleShot* or *Continuous* mode. Use *Stop Condition* to choose between *None* and *On Limit Fail* and so on. The *ESC* hardkey closes the current drop-down list. In general, this accepts the selection or parameter input (without pressing *Enter*).

7 GSM Measurements: CMW Configuration

This section provides a very detailed description of the CMW configuration and the repetitive steps required for setting up and clearing down a connection between the mobile phone and the tester.

The first step is to create a universal configuration on the CMW for all GSM measurements and to save it to the instrument. The next step is to set up the first connection and start a TX measurement. Without going into any detail regarding the measurement results, this portion of the document is intended to get familiar with the individual steps, making reiterations unnecessary in the later measurements.

Note: All screenshots in this application note were taken from measurements of a typical mobile phone using the GSM900 frequency band. The mobile phone is equipped for Power Class 4. If testing mobile stations that use a different frequency band or Power Class 5, the CMW configuration must be modified accordingly. The *mobile capabilities* of the DUT can be displayed on the CMW the first time it is registered with the tester.

7.1 Preparation, Test Setup

The CMW establishes a GSM cell for performing signaling measurements, or more specifically, it creates two bidirectional duplex channels on two different frequency pairs. The first channel handles the broadcast signaling for all potential wireless subscribers in the cell in parallel. This channel is therefore simply called the broadcast channel (BCCH). (In fact, this channel uses embedded channels to handle the registration, the time and frequency synchronization and the connection setup and cleardown.)

The second channel carries the voice traffic (traffic channel, TCH) or the packet data (packet data channel, PDCH). This channel is reserved for one individual subscriber, in this case the DUT. This is the channel that will be used for all measurements, specifically the downlink for the RX tests and the uplink for the TX tests.

In addition to voice and data, the TCH and the PDCH also carry signaling information intended for a specific subscriber over the embedded logical channels SACCH / FACCH or PACCH. These channels control the power on the mobile phone and change the modulation and coding schemes, for example.

In the following exercises, the TCH/PDCH always uses the RF1COM port and the BCCH uses the RF3COM port. Both are located at the front of the CMW.

The DUT must have an RF link to the CMW without permitting any transmit power leaks from the tester or the DUT. This is where the R&S®CMU-Z11 or R&S®CMW-Z11

shielded chambers come in. They can be used to characterize the mobile phone with reproducible results.

Each of these chambers is equipped with an internal coupling antenna that is accessible from the outside via a type N connector. This is connected to RF1COM and RF3COM via a power splitter, see Fig. 7-1.
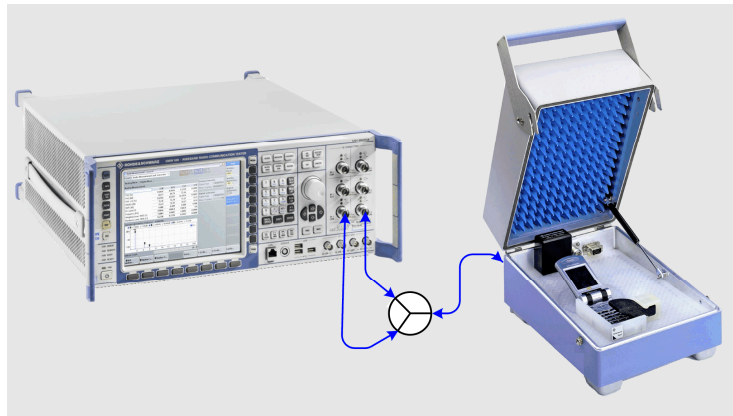

Fig. 7-1: Hardware test setup.

► Connect a power splitter / combiner[15] to RF1COM and RF3COM.

► Connect the RF power splitter to the antenna port on the shielded chamber.

The path attenuations, i.e. the coupling attenuation of the shielded chamber, the insertion loss of the splitter and the attenuation on the RF cable are compensated later in the CMW.

SIM card

Special SIM cards (also available from Rohde & Schwarz) are used for testing mobile stations. These prevent connections from being set up to existing wireless networks and make it possible for the tester to activate test loops in the DUT.

► Switch off the test telephone (DUT).

► Insert the test SIM.

---

[15] A suitable power splitter / combiner is model ZFSC-2-2500 from the Mini Circuits company.

RESET

► Reset the CMW. Press the blue *RESET* hardkey at the top left edge of the instrument. Globally reset all applications when prompted, then select *Preset* in order to accept the global default values predefined in the CMW.
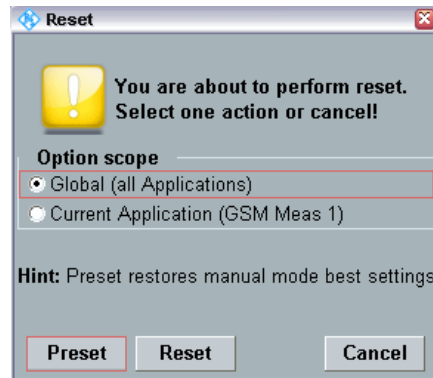
Fig. 7-2: CMW preset.

These default values ensure a reproducible starting point. Building on that, the next step is to create an appropriate universal instrument configuration and save it as an instrument setup. This will then be used as the starting point for all further measurements.

7.2 Configuring and Starting the GSM Signaling Task

General information and selecting tasks

Each task has a main view. The name of the task is displayed in the heading, e.g. *GSM Signaling, GSM TX Measurement Multi Evaluation, GSM RX Measurement*, etc. Each task has its own configuration window.

Tasks can run in the foreground. In this case the screen contents and the softkeys "belong" to this task. Tasks can also run in the background. During TX or RX measurements in signaling mode, for example, the signaling task runs in the background.

First select the GSM signaling task as described in section 6.1.

► Press the hardkey *SIGNAL / GEN*.

The *GSM Signaling Controller* window appears, see Fig. 7-3 on page 47.

The CMW used here is equipped with two channels. If a single-channel instrument is being used, only one generator will be displayed.

► Select the GSM signaling task.

► Deselect other tasks if there are selectes ones.

The *signaling* task has not yet been started at this point (the *state* is *OFF*). This task is started later using the *ON/OFF* hardkey.
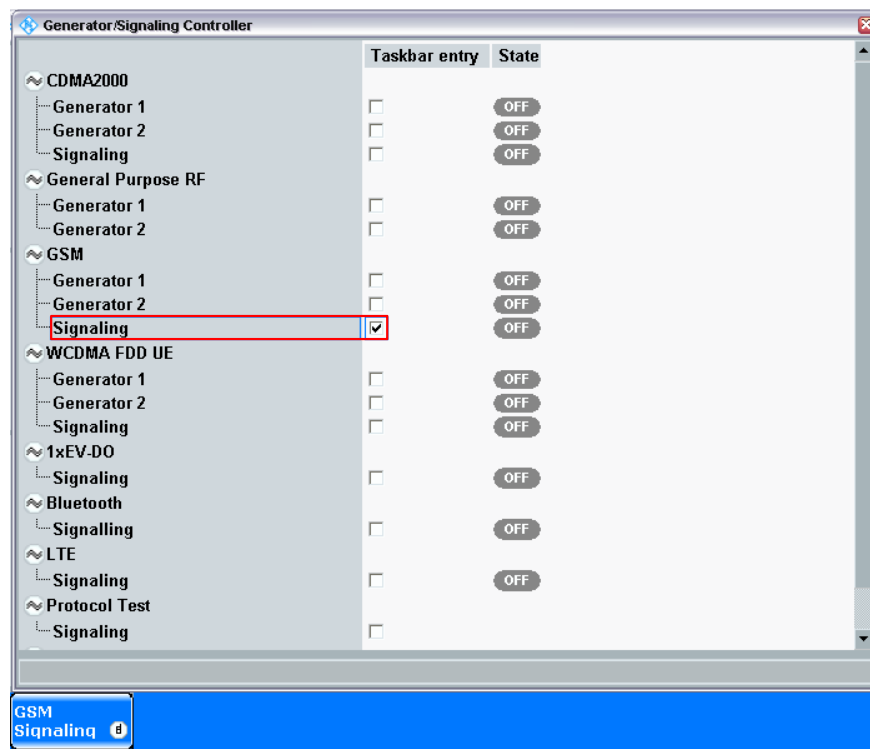

Fig. 7-3: Selecting the signaling task.

► Press the hardkey *ESC*.

The active window closes and returns to the main view for GSM signaling.

Note: Always use the *ESC* hardkey to close windows! The hardkey *CLOSE* also closes the current window. However, if *CLOSE* is inadvertently pressed while in the task main view, it will stop the current task!

The next step is to configure the signaling task so that both circuit-switched and packet-switched connections are possible between the DUT and the tester.

However, first a brief look at the contents of the main view for the signaling task:

Display and input fields in the GSM Signaling main view

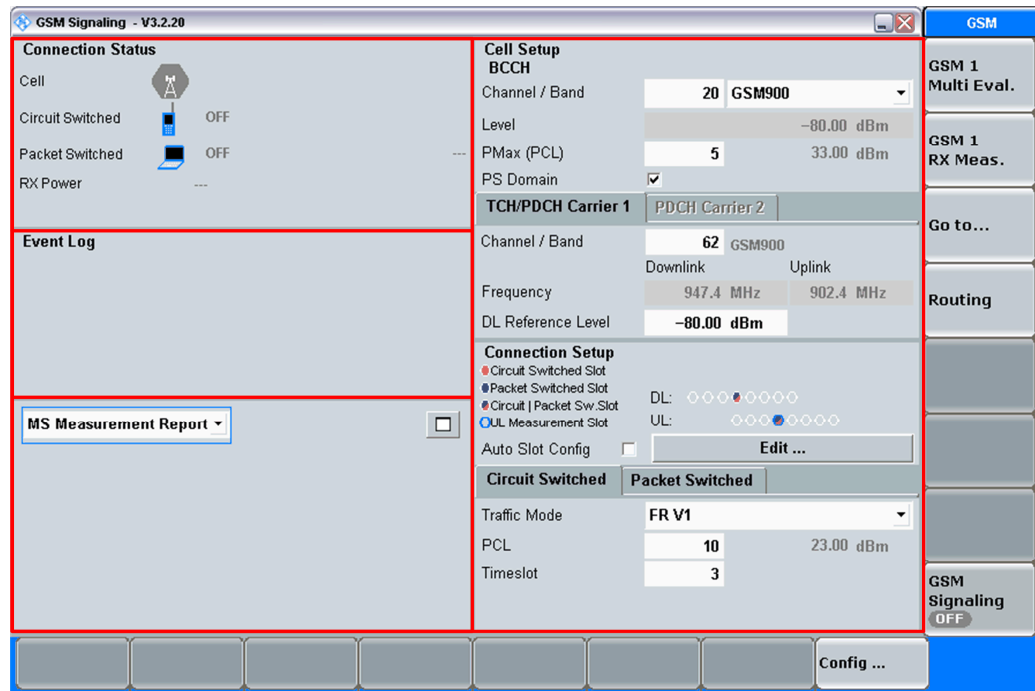See the areas boxed in red in Fig. 7-4.

Fig. 7-4: Display and input fields in the GSM Signaling main view.

The three red areas on the <u>left</u> side of the screen are indication windows.

In the *Connection Status* field, you can see that the test cell has not yet been established by the gray "cloud" around the transmitter mast. (An active cell has a green "cloud".) So, there is not yet a connection between the DUT and the tester. The *Circuit Switched* and *Packet Switched* (connections) are both OFF, and no *RX Power* is displayed.

The *Event Log* and the *Measurement Report* sections are still empty. The CMW log will eventually be displayed in the Event Log window. During operation, the Measurement Report will display the log for the mobile station under test. However, you can also display the *mobile capabilities* and the DUT-specific *MS info* in this section.

The <u>right</u> side of the screen is used to enter or modify parameters. In Fig. 7-4 the default settings after *RESET / Preset* can be seen.

► At the BCCH, select the PS Domain checkbox. This makes it possible to set up PS calls as well.

► Retain the default settings for TCH/PDCH: Channel 62, DL Reference Level –80 dBm (this will be covered in more detail later).

The *Connection Setup* parameters are of particular importance. These are the most critical physical settings, including the slot selection, the power levels used and the modulation and coding schemes. This is where you will make the most frequent changes.

Auto Slot Config should never be selected. The slot will be configured manually.

► Click *Edit ...*.

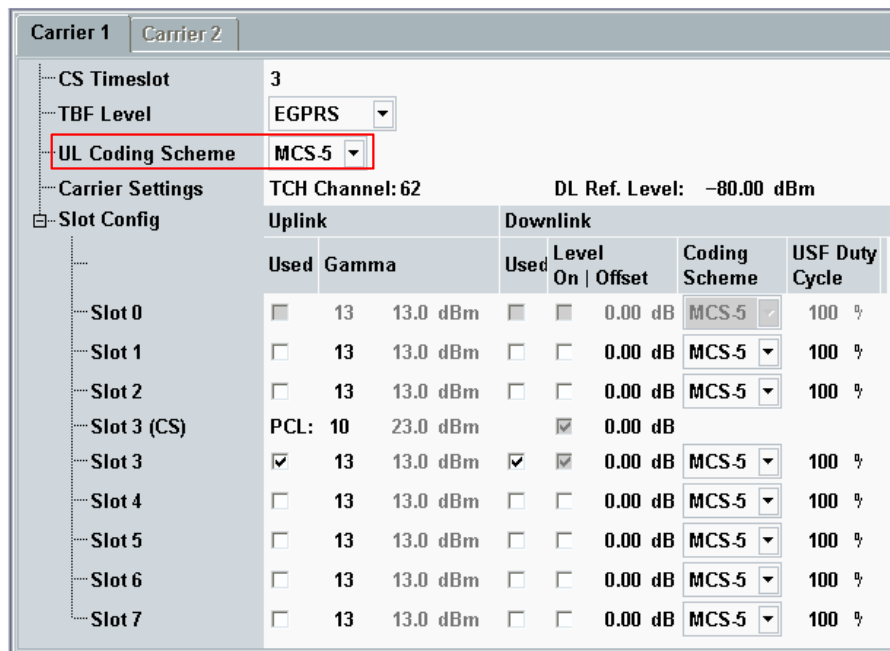This takes you to the Slot Configuration window.

Fig. 7-5: Slot configuration with the critical burst parameters.

By default, slot 3 is used for both circuit-switched and packet-switched connections. That is a reasonable choice, because if a PS measurement is started after a CS measurement, the slot does not have to be changed in the measurement task.

Only the first row (*CS Timeslot*) and the *Power Control Levels PCL* options for slot 3 refer to the circuit-switched mode. All other settings are used for the packet-switched configuration.

The *TBF Level* (i.e. the technology level of the PS connection being set up) is set to Enhanced GSM Packet Radio Service EGPRS. This means that modulation and coding schemes MCS-1 though MCS-9 can be selected. MCS-1 through MCS-4 use GMSK modulation and MCS-5 through MCS-9 use 8-PSK modulation. The higher the index, the higher the data rate will be, but at the cost of the respective error correction.

► Set the *UL Coding Scheme* to *MCS-5*. This sets 8-PSK.

► Also set the *Downlink Coding Scheme* to *MCS-5*.

The <u>Uplink</u> level will now be set.

For circuit-switched signals, the TX output level is defined by the *Power Control Level PCL,* and for *packet-switched* signals, it is defined by the *Gamma* value. The following table shows the relationship between the output level, *PCL, and Gamma*.

Mobile Output Power						
Power Class 2 | 3 | 4 | 5				**Power Control Level PCL**	**Gamma**	**TX Output Level dBm**
x				2	0	39
x	x			3	1	37
x	x			4	2	35
x	x	x		5	3	33
x	x	x		6	4	31
x	x	x	x	7	5	29
x	x	x	x	8	6	27
x	x	x	x	9	7	25
x	x	x	x	10	8	23
x	x	x	x	11	9	21
x	x	x	x	12	10	19
x	x	x	x	13	11	17
x	x	x	x	14	12	15
x	x	x	x	15	13	13
x	x	x	x	16	14	11
x	x	x	x	17	15	9
x	x	x	x	18	16	7
x	x	x	x	19	17	5
x	x	x	x	etc.	etc.	etc.

Table 7-1: For setting the TX uplink level.

The level of a packet-switched signal (for GSM900) is calculated as

$L_{P/1mW}$ = 39 dBm – Gamma $_*$ 2 dB

Later measurements will use PCL = 5 for the maximum output of a voice connection, and Gamma = 6 for the maximum output of a data connection. Low power levels will use PCL = 19 or Gamma = 17.

 PCL = 10 and Gamma = 13 are the default settings.

Note that mobile phones do not set their own transmit power. This is always set by the base station (in this case, the CMW).

The level of the downlink signal is referred to as the *DL Reference Level* (*DL Ref.Level)* because it can further be decreased by up to 40 dB in each individual slot. This option is not used in these exercises.

(The uplink status flag USF is meaningful when multiple PS connections are assigned to the same slot, distributed over the frames. It is not relevant here.)

► Press *ESC* to return to the GSM signaling main view.

The remaining settings on the right side of the GSM signaling main view (Fig. 7-4 on page 48) are also displayed in the configuration window of the signaling task. Go to the signaling task now to set these:

► Press the softkey *Config...*

The configuration window of the GSM signaling task opens. The next few pages describe only those fields that are used for the practice measurements and those that deviate from the default settings. Sublevels that are not of any significance for the measurements here are not covered.
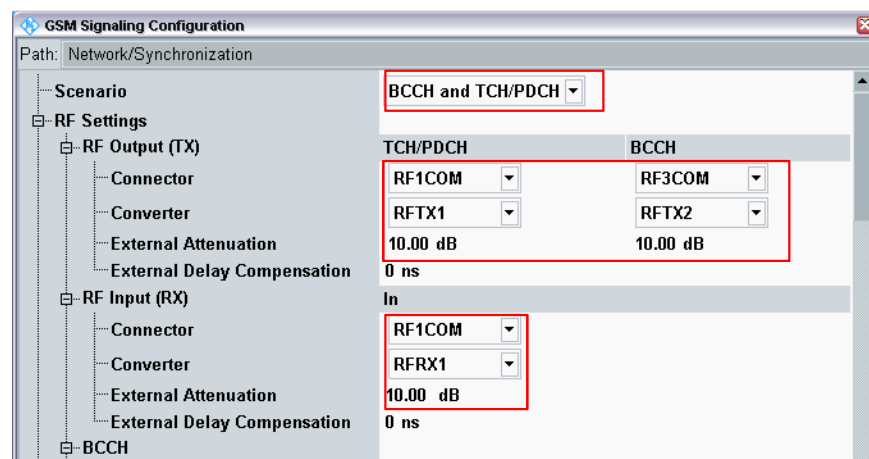
Fig. 7-6: GSM signaling configuration 1.

► Select *BCCH and TCH/PDCH* as the scenario. This ensures that the CMW sets up both duplex channels, just like a real GSM base station (this is not the default setting).

With this scenario, the CMW always uses the RF1Com port for TCH/PDCH and the RF3COM port for BCCH.

► Define the path attenuations for the output and input with an initial value of 10 dB under *External Attenuation*. This is a preliminary value that will be adjusted later.

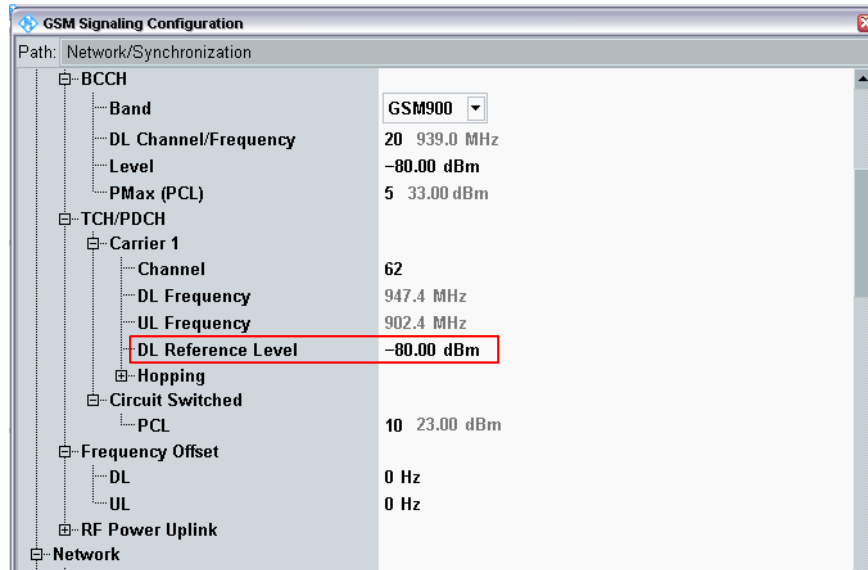Leave the parameters in Fig. 7-7 at the default settings:

Fig. 7-7: GSM signaling configuration 2.

Note: The *DL Reference Level* can also be edited in the connection setup.
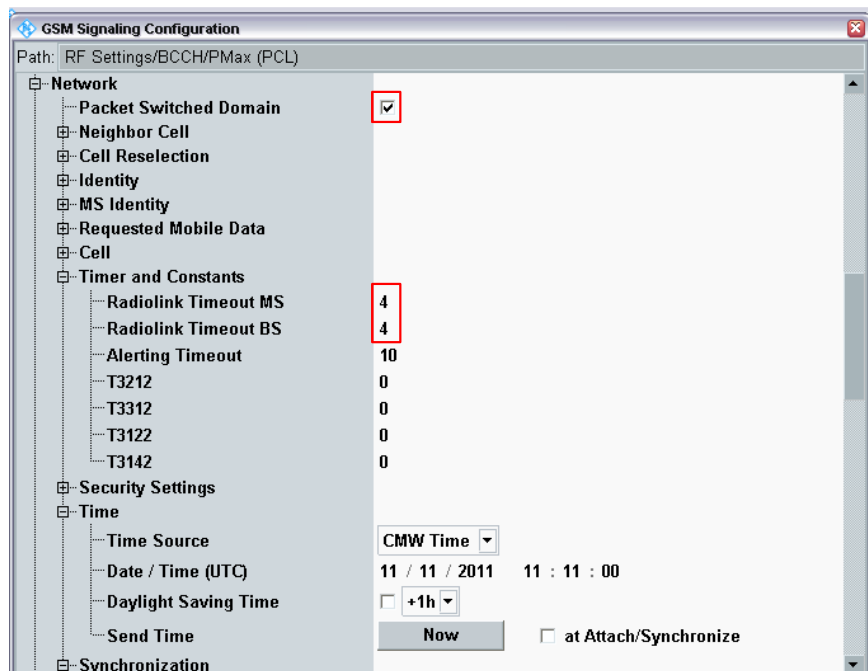

Fig. 7-8: GSM signaling configuration 3.

The *Packet Switched Domain* setting here is mirrored from the entry in the signaling main view. With the checkbox selected, PS devices can also synchronize.

If a GSM radio link is noisy or has interference at low field strengths, the decision whether to maintain or clear down the connection is made depending on whether the signaling channel *SACCH* can still be received with acceptable quality.

The parameter *Radiolink Timeout* in Fig. 7-8 on page 52 determines after how many *SACCH* blocks that can no longer be evaluated the radio link is disconnected. A value of 4 in this field corresponds to about two seconds.
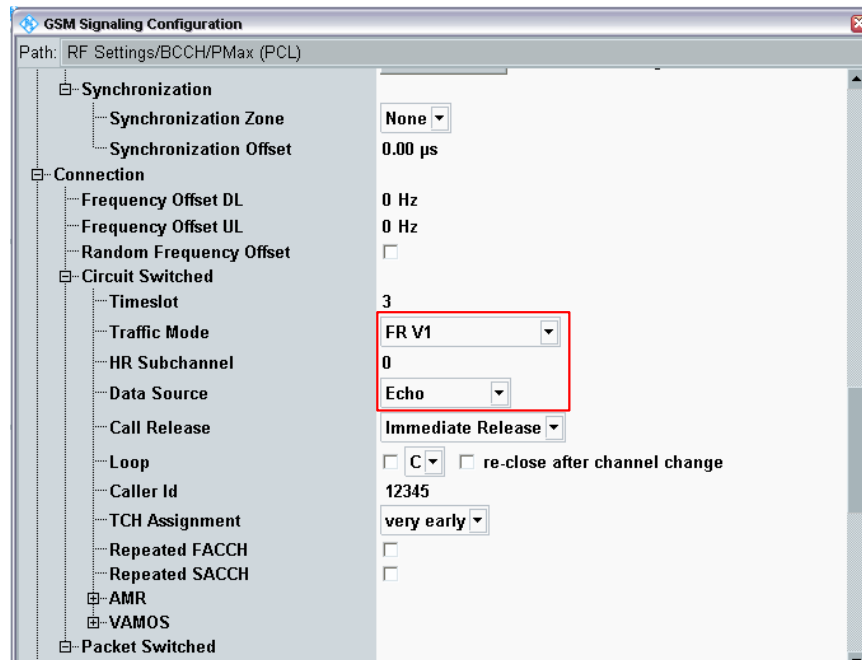

Fig. 7-9: GSM signaling configuration 4.

For (circuit-switched) voice connections, the CMW uses the *Full Rate (FR)* speech coder Version 1 (*V1*) specified in the standard as the default. Do not change this setting. *Half Rate (HR)* subchannels are not used.

Set *Data Source Echo* to make the CMW loop the received speech frames back to the DUT.

The *Caller Id* is the telephone number that the CMW assigns to itself. However, when using a test SIM to start a call from the mobile phone to the CMW (Mobile Originated Call, MOC), any phone number can be dialled.
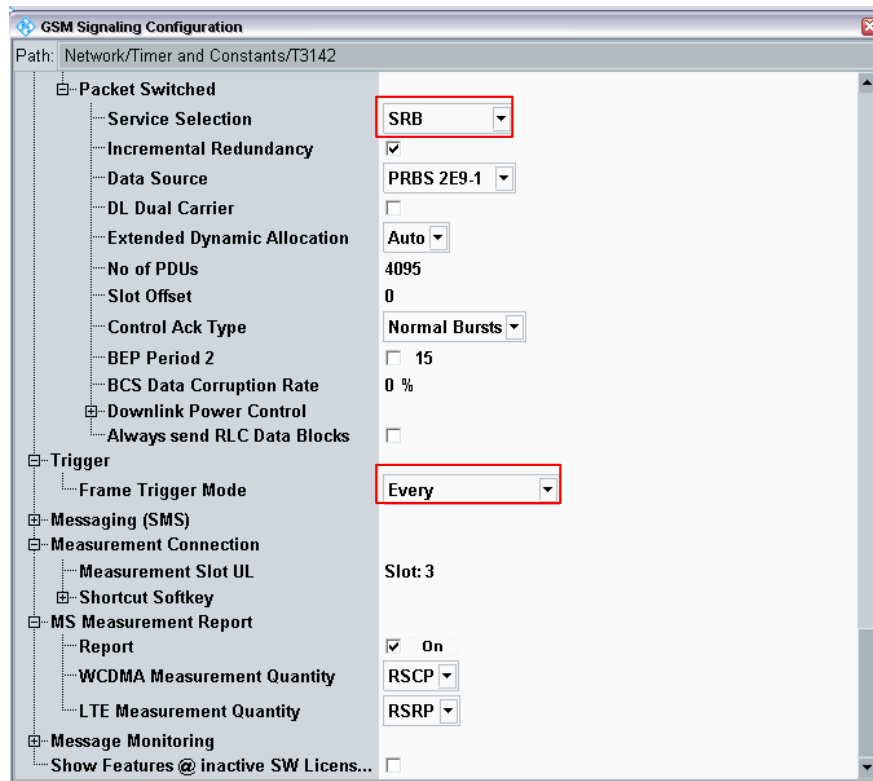
Fig. 7-10: GSM signaling configuration 5.

For bit error measurements, the packet-switched service *SRB* sets up one of the possible test loops in the DUT. (The packet-switched services are covered in more detail in the RX measurements.)

The (internally generated) trigger signal (used later) should appear in every frame.

The measurement report can be enabled or disabled.

This completes the configuration of the signaling task for circuit-switched and packet-switched connections.

► Press the hardkey *ESC*.

The configuration window closes and returns to the main view for GSM signaling.

These settings will be saved in the CMW as an appropriate complete configuration after the multi evaluation task and the RX task have been configured.

What power level (watts) is defined by PCL = 5, what level is defined by PCL = 10?

How large is the frequency spacing between the uplink and the downlink for GSM900?

When Data Source Echo is selected, what would be heard in the DUT receiver?

7.3 Registering the Mobile Phone

You must learn the following procedures so well that they become almost automatic!

The CMW shall show the GSM signaling main view.

The DUT should still be switched off.

1. Press the *GSM Signaling* softkey on the CMW. The softkey turns blue.

2. **Switch on the signaling.** (Press the ON / OFF hardkey on the CMW.)

In the Connection window, the "cloud" around the transmitter mast turns green. The signaling software is started.

3. **Wait** until *Circuit Switched* and *Packet Switched* change to *ON*.

4. **Switch on the DUT** and position it in the shielded chamber.

Wait until the DUT registers with the CMW. This can necessarily take more than 1 minute.

5. **Wait** until the DUT has synchronized with the CMW tester.

The circuit-switched status changes to *synchronized* and the packet-switched status changes to *attached*, see Fig. 7-11 on page 56.

If the DUT is still not synchronized after a maximum of 2 minutes:

►   Switch off the DUT and stop the signaling task.

►   Check the cabling and the level settings. Increase the downlink level if needed.
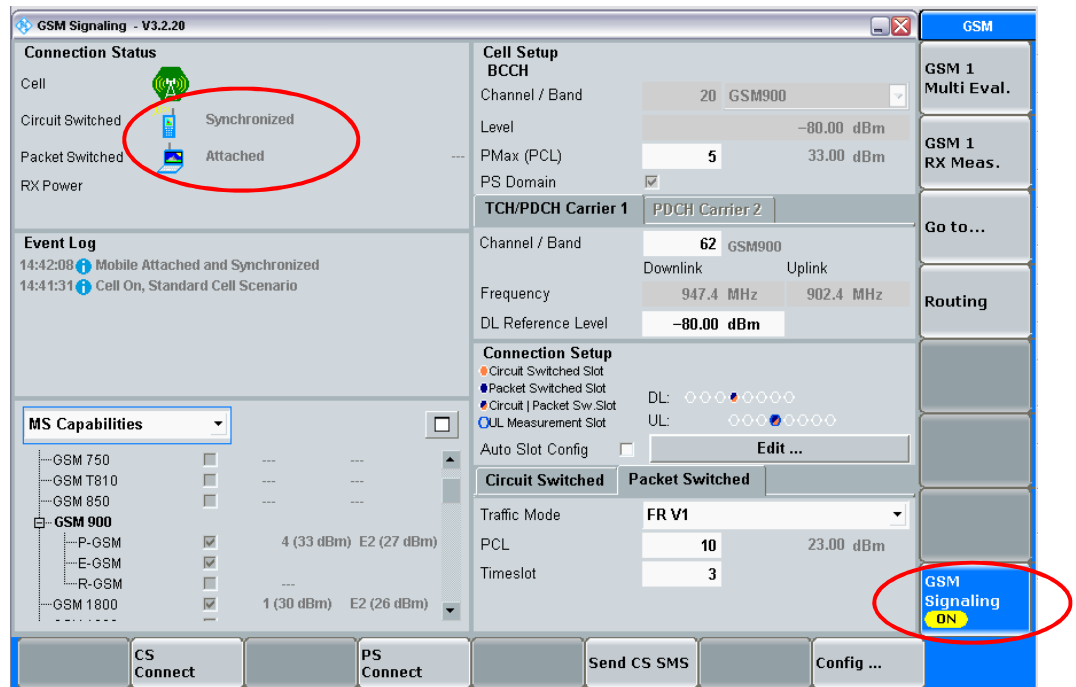
►   Start again at step 1.

Fig. 7-11: Registering the mobile phone.

The softkeys *CS Connect* and *PS Connect* appear (only) when *Signaling = ON*. However, they are not enabled until the DUT is synchronized!

► Check the event log.

► Check the MS capabilities for the DUT. Make note of the possible frequency bands, the corresponding power classes for the various modulation modes and the supported multislot classes.

► Display the MS info.

7.4 Configuring the TX Task GSM Multi Evaluation

The CMW was specifically developed to minimize measurement times. Therefore, unlike other wireless communications testers, there are no individual tests, but rather only one task that performs all required TX tests and one task that performs all required RX tests.

The task for the GSM TX measurements is called the *GSM Multi Evaluation* task. This task uses one recorded GSM frame (eight timeslots) to obtain an entire set of readings simultaneously. Results are evaluated in the time domain, spectral domain and baseband domain. If certain results offered by the instrument are not needed, that specific evaluation can be disabled, making the measurement run even faster.

Tests are measurements in which the result is checked whether defined limits are satisfied or not. By default, the CMW uses the measurement parameters and procedures along with the limit values and tolerances from ETSI standard 3GPP TS 51.010. You can also set limits manually.

Table 7-2 identifies the chapter in the ETSI standard that is followed for TX measurements.

A distinction is made here between power measurements (in the time domain), modulation quality measurements (in the I/Q domain) and spectrum measurements (in the frequency domain).

Subject	TX tests	3GPP TS 51.010
Power (time domain)	Transmitter output power and burst timing	Sections 13.3, 13.7, 13.16.2, 13.17.3
Modulation (I/Q domain)	EVM, I/Q offset	Section 13.17.1
Modulation (I/Q domain)	Frequency and phase error	Sections 13.1, 13.6, 13.16.1, 13.17.1
Spectrum (freq. domain)	Output RF spectrum	Sections 13.4, 13.8, 13.16.3, 13.17.4

Table 7-2: GSM TX measurements covered by the multi evaluation task.

This application note shows TX tests from each of these areas.

(Many tests in line with the ETSI standard require additional instrumentation, such as signal generators as additional interferers, spectrum analyzers or fading simulators. These tests can also be performed (in conjunction) with the CMW radio communication tester. However, they are not covered in this application note.)

Selecting the GSM measurement tasks

► Press the hardkey *MEASURE*. A list of the available measurements is displayed, see Fig. 7-12 on page 58.

► For TX measurements, select *GSM - Multi Evaluation 1.*

(Like in the SIGNAL / GEN window, there are two multi evaluation tasks for the two-channel tester used for Fig. 7-12 on page 58.)

► For RX measurements, select the *GSM - RX Measurement* task.

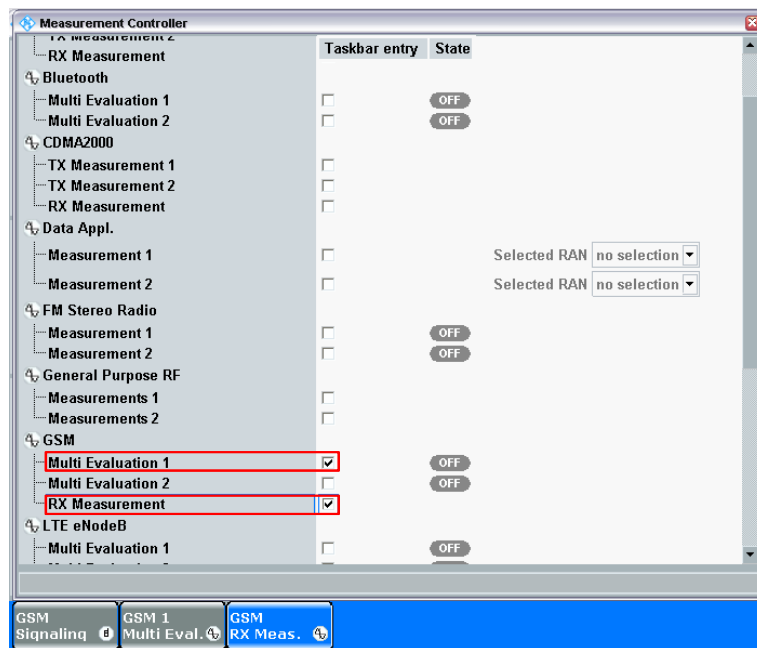► Clear the checkboxes for any other selected measurement tasks.

Fig. 7-12: Selecting the measurement tasks.

Although the two selected tasks are not yet activated, they will already appear in the task bar.

Configuration

► In the task bar, press *GSM - Multi Eval.*

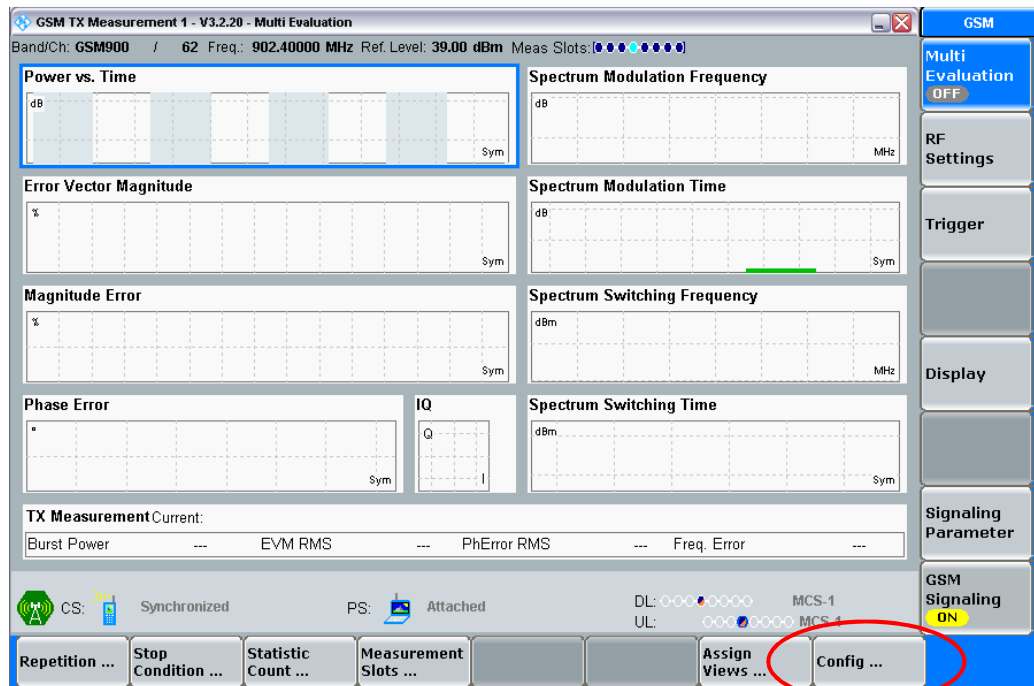The empty result window for the multi evaluation task opens.

Fig. 7-13: The empty result window for the multi evaluation task.

► Press the softkey *Config....*

The *GSM Multi Evaluation Configuration* window opens, see Fig. 7-14. Most of the sublevels are still closed. The (default) settings behind will not be discussed here.

Important is the *Scenario*:

► Select the *Combined Signal Path* option.

This setting instructs the GSM multi evaluation task to take many settings from the configuration window for the signaling task. For example, the frequency channels and the external attenuation.
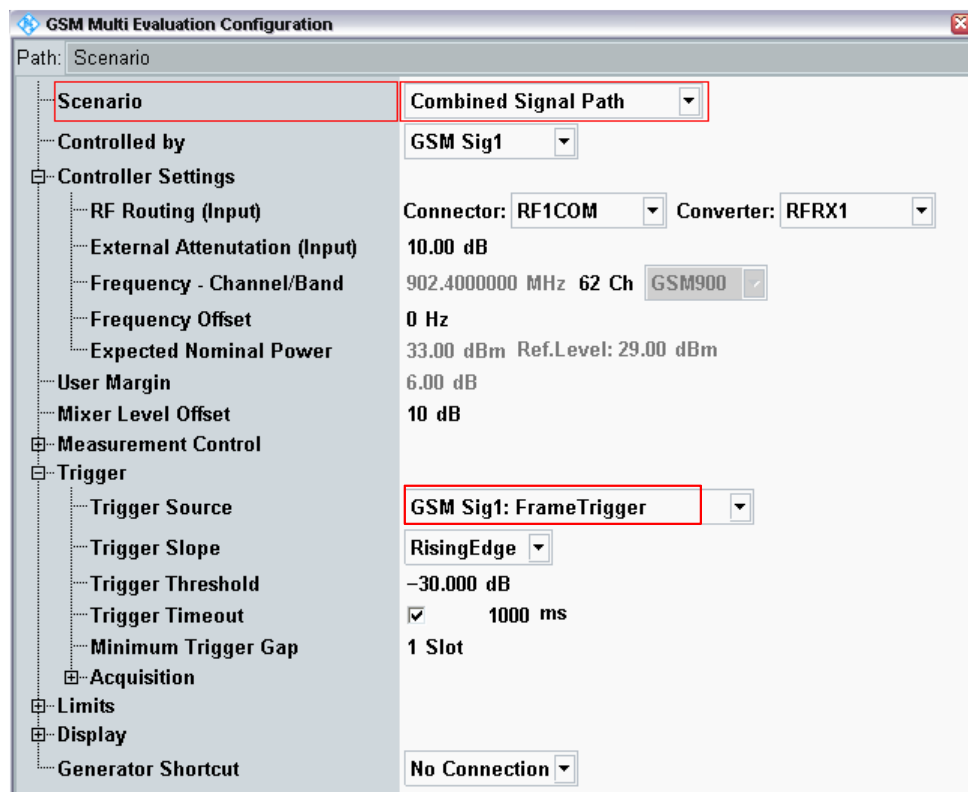

Fig. 7-14: GSM multi evaluation configuration.

Another important selection is the correct *Trigger Source.* In this case,

► select *GSM Sig1: Frame Trigger.*

This allows the CMW software to deliver the trigger, and not the DUT signal. This eliminates the setting problems that can arise with a power trigger, for example.

Keep the default settings for all other parameters.

This completes the configuration of the multi evaluation task.

► Press the hardkey *ESC.* The active window closes and returns to the main view for GSM signaling.

7.5 Configuring the RX Task

► In the task bar, press *GSM - RX Meas.*

The empty results window for the RX measurement task opens.
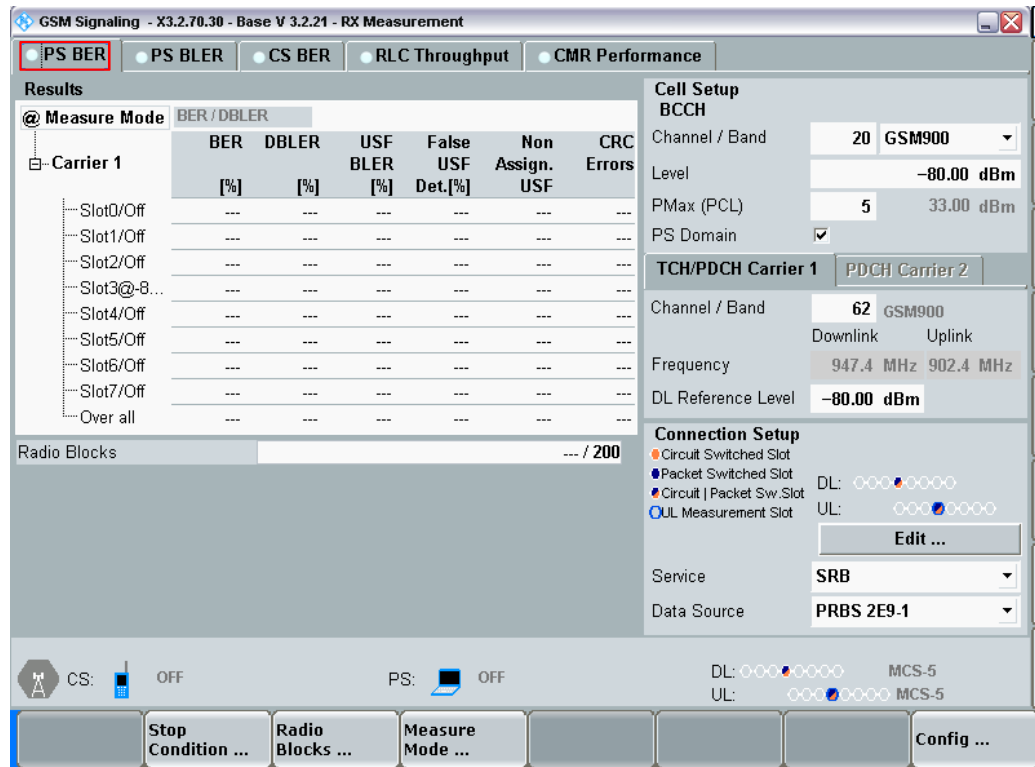

Fig. 7-15: Configuring the PS BER measurement modes for the RX measurement task.

A series of horizontal tabs are used to select the different RX tests. The first three will be discussed in more detail later.

ı PS BER   Packet-switched bit error rate

ı PS BLER   Packet-switched block error rate

ı CS BER   Circuit-switched bit error rate

For the PS BER measurement, set the following

► *Stop Condition* to *None*.

► *Radio Blocks* to *200*. This number of radio blocks corresponds to a measurement duration of just under four seconds.

► *Measure Mode* to *BER / DBLER*. This instructs the software to count bit errors (not block errors).

► Check and modify the *Service* if needed. It should be set to *SRB* (switched radio block). This closes an RX loop that mirrors each burst back to the tester, without error correction.
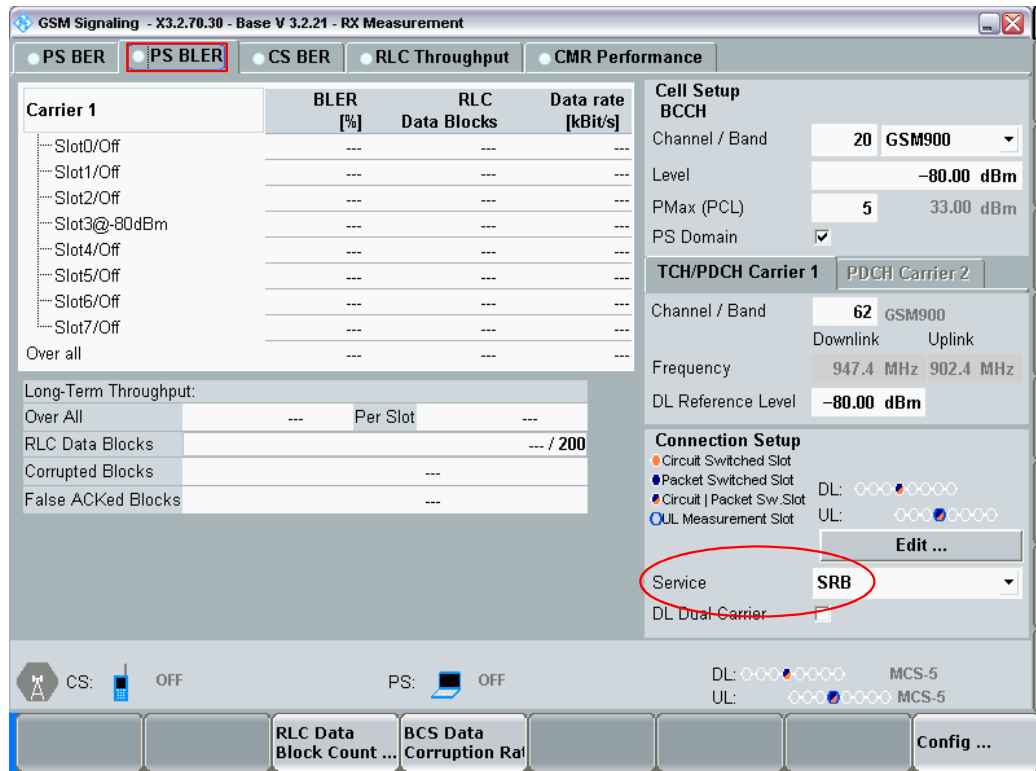
► Go to the PS BLER tab.

Fig. 7-16: Configuring the PS BLER measurement modes for the RX measurement task.

Define the following:

► RLC Data Block Count = 200.

When the PS BLER measurements are next in line, the parameter *Service* must be set to *BLER* (before the connection setup). We do not change it here, because this parameter applies for all RX measurements. And *SRB* is needed for the PS BER tests which are carried out at first.

► Go to the CS BER tab.

Define the following:

► *Stop Condition* to *None*. Another option would be to stop the measurement if a defined error rate is exceeded.

► *Bursts* to *200*. This number of radio blocks corresponds to a measurement duration of just under one second.

► *Measure Mode* to *Burst by Burst*. As with PS BER, this closes an RX loop that mirrors each burst back to the tester, without error correction.
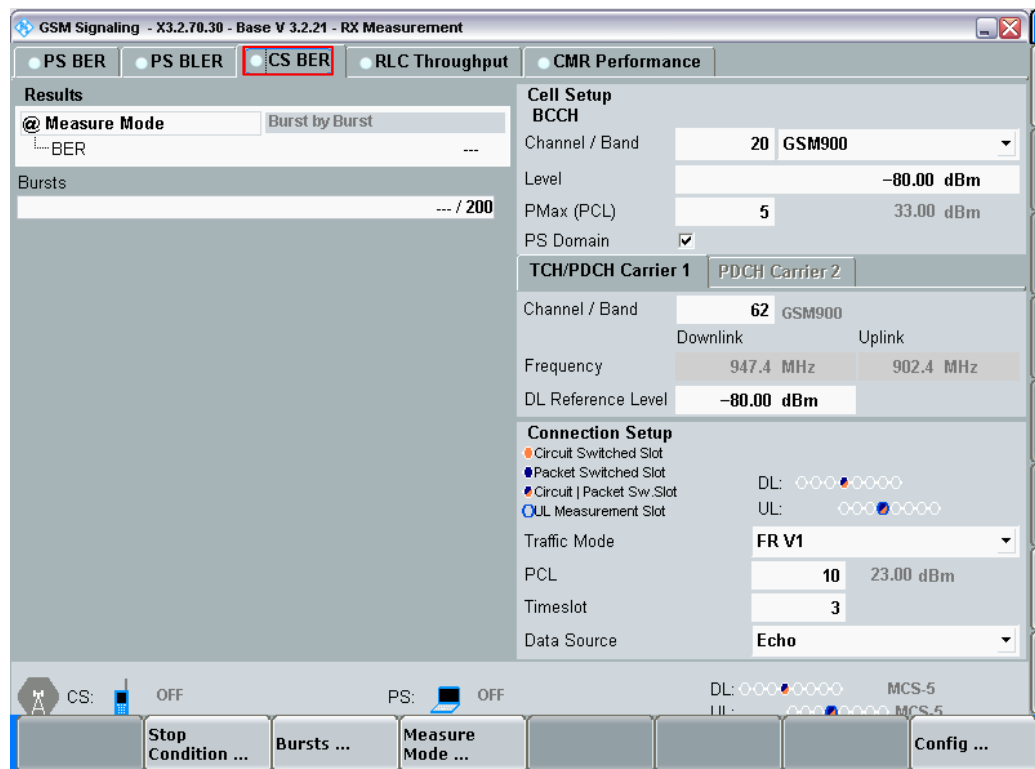
Fig. 7-17: Configuring the CS BER measurement modes for the RX measurement task.

This completes the configuration of the RX measurement task.

7.6 Saving the Instrument Configuration

After the signaling task, multi evaluation task and RX task have been configured these settings will be saved as an appropriate complete instrument configuration.

A keyboard and mouse are recommended for this procedure.

► Press the hardkey SAVE / RCL.

► Create a new folder (Add folder softkey).

► Save the instrument configuration (Save softkey) as file *LabConfig0.dfl*

In the exercise GSM Measurements: Burst Power and Timing, this configuration will be slightly modifed to bring in the actual *external attenuation* value obtained during that measurement. You therefore should not skip that exercise!

This instrument configuration will be reloaded before every GSM measurement. This prevents that unsuitable or "hidden" manual settings will cause unexpected results.

7.7 Connection Setup

The DUT should still be switched off.

► *RESET*[16] the CMW and load the instrument configuration *LabConfig0.dfl.*

► Open the GSM signaling main view.

► Switch the GSM signaling task on.

Once the connection status for *Circuit Switched* and for *Packet Switched* has switched to *ON*:

► Switch on the DUT and wait until the status for *Circuit Switched* or *Packet Switched* has changed to *Synchronized* or *Attached.*

If the DUT is still not synchronized after a maximum of two minutes:

► Switch off the DUT and stop the signaling task.

► Check the cabling and the level settings. If necessary, increase the downlink level to –60 dBm.

► Repeat these steps (after the *RESET*).

Circuit Switched

► Press the softkey **CS** Connect.

► When the DUT "rings", open the shielded chamber and "pick up".

► Close the shielded chamber.

Packet Switched

► Press the softkey **PS** Connect.

No "pickup" is required!

What is the connection status called?

At what level (dBm) should the DUT transmit ?

What is the power (mW) associated with this level? (Levels are relative values, an example unit is dBm. Power is an absolute value, an example unit is mW).

7.8 Starting the Multi Evaluation Measurement Task

► In the vertical softkey bar, press *GSM 1 Multi Eval.*

► Press the hardkey *ON/OFF.*

---

[16]No *PRESET* is needed in this case because all settings have been reloaded.

7.9 Measurement Results / Screens

The measurements start. A results screen appears, comparable to that shown in Fig. 7-18.

This provides a quick overview of the DUT transmit signal. This screen includes 10 result windows with primarily graphical results.

In the measurements described later, the most important windows will be maximized to provide a better view. This will bring a number of additional details to the screen that are not visible here, such as scaling and more controls.
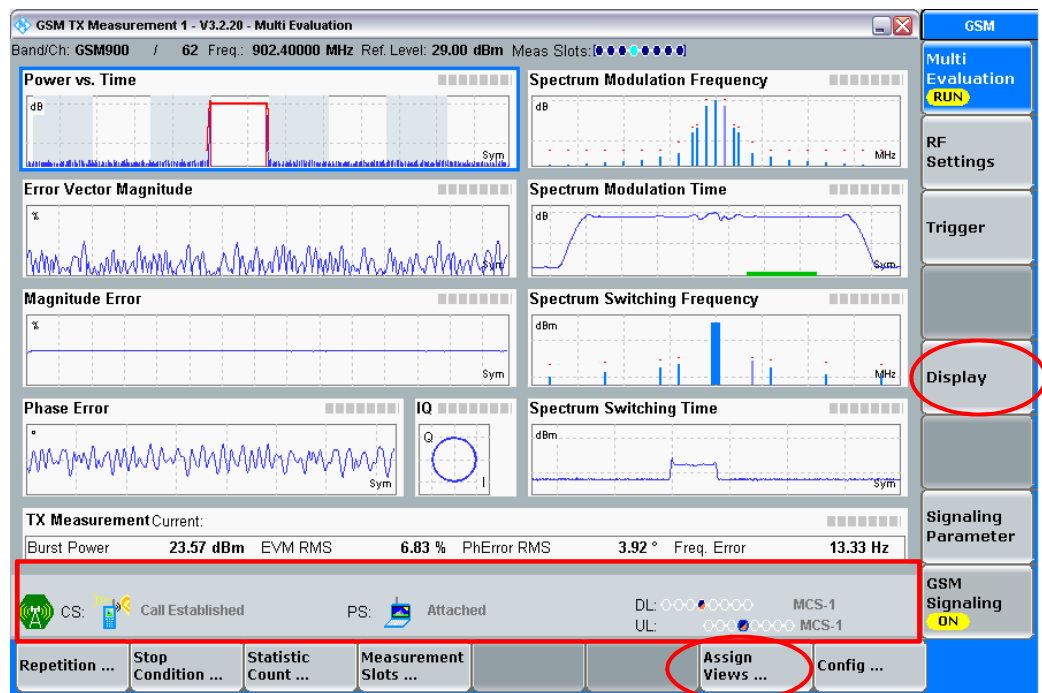

Fig. 7-18: GSM TX overview.

In the *Power vs. Time* window, the eight timeslots of one frame can be seen, along with the identified burst and (in red) the power template that the burst must not violate. The scaling is performed automatically.

The Error Vector Magnitude window displays the EVM vs. symbol. The ISI of the GMSK modulation was deducted by the CMW software. (Because of the ISI, this measurement is not included in the GSM standard for GMSK, but it can be very useful in R&D.) This display includes a maximum 149 symbols, i.e. just slightly more than the useful part of a burst.

The Magnitude Error and Phase Error windows also display just slightly more than the useful part of a burst, again with a maximum of 149 symbols.

The I/Q window is used to identify the modulation type quickly.

The Spectrum Modulation Frequency and Spectrum Switching <u>Frequency</u> windows show the particular components at the fixed frequency offsets defined in the standard. The ETSI limits are also displayed.

The Spectrum Modulation Time and Spectrum <u>Switching Time</u> windows show the power versus time at one of the frequency offsets. The display span for Spectrum Modulation Time is somewhat larger than a burst, and for Spectrum Switching Time it is almost two frames.

There are two steps to determine which result windows will appear on the screen.

▪ The *Assign Views...*softkey in the GSM multi evaluation task is used to define which results from the recorded TX signal of the MS have to be <u>evaluated</u>:
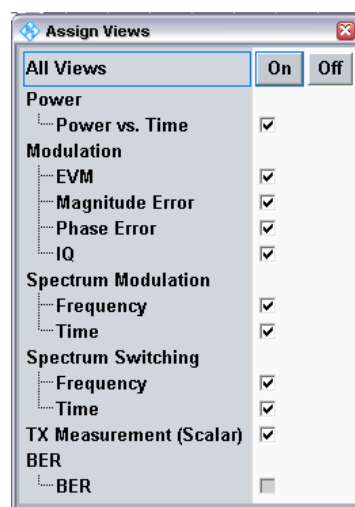

Fig. 7-19: Assigned views.

If not all results need to be evaluated, the checkboxes for those results should be cleared. This will speed up the measurement. But this is not necessary during manual operation, so leave all views selected for now.

▪ Go to *Display / Select View...* to display either all <u>evaluated</u> results together (as *Overview*) or a single one. In the case of the latter, the result is zoomed to maximum size.

If only one result window is displayed, the CMW uses the still mostly remaining display area for additional information. For example, burst power then offers numerical information about the power in the individual slots, the associated training sequence TSC, the burst type and the relative burst timing. Or different measurement modes can be set, such as Min / Max / Average. The graphical displays are now also scalable.

In place of a graphical result display, most measurement results can also be output as pure numerical values.

In addition to the current measurement displays, the CMW keeps the user informed of the current connection status in the status field over the horizontal softkey bar, see Fig. 7-18 on page 64.

As seen here (by the green cloud), signaling is active. A CS call is set up (*CS Call Established*). The downlink (DL) and uplink (UL) use timeslot 3 (blue / orange marker). In the case of a PS connection, *Modulation and Coding Scheme 1 (MCS-1)* would be used. Uplink and downlink slots 3 are preselected for both CS and PS.

Note: The CMW displays measurement results only when a signal is found. This means that the idle burst is not displayed!

► Try out different result windows.

► Vary the settings on the screens offered by the softkeys *Repetition, Stop Condition, Statistic Count and Measurement Slots*.

► Clear down the CS or PS connection (*GSM Signaling* / ... *Disconnect*).

► Practice the connection setup / cleardown and switch between the signaling and multi evaluation task and their configurations.

► Change the uplink level during a CS and during a PS measurement (in the connection setup).

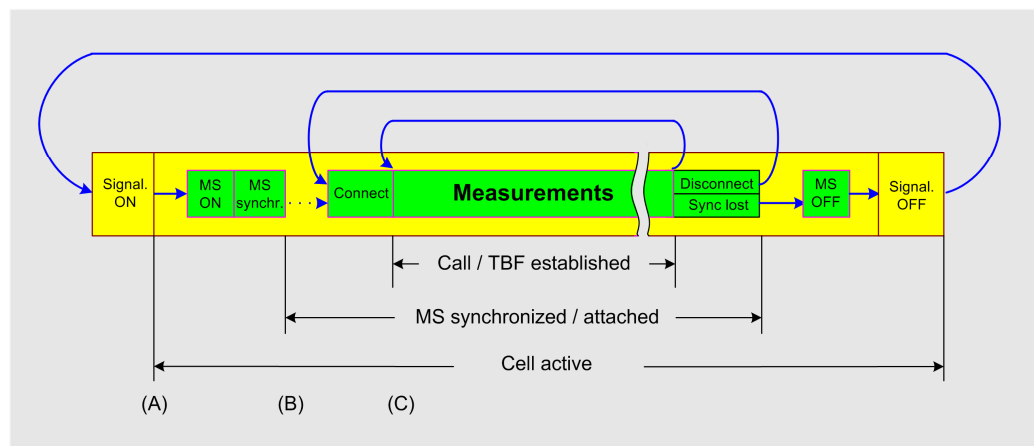► Repeat chapter 5, Sequence of Wireless Communications Measurements.

Fig. 7-20: Schematic flow of wireless communications tests.

After this preliminary work, you are ready to perform the four basic GSM measurements described in the next chapters.

8 GSM Measurements: Burst Power and Timing

This section compares the bursts of a voice call against those in a data call. The discussion focuses on the power versus time PvT and the I/Q constellation.

Before this, the insertion loss of the RF measurement paths will first be fine tuned. The resulting new instrument configuration *LabConfig.dfl*. will replace the initial instrument configuration *LabConfig0.dfl*.

Preparation

The DUT should still be switched off.

► *RESET* the CMW and load the instrument configuration *LabConfig0*.dfl

► Open the GSM signaling main view.

► Switch the GSM signaling task on.

Once the connection status for *Circuit Switched* and for *Packet Switched* has changed to *ON*:

► Switch on the DUT and wait until the status for *Circuit Switched* or *Packet Switched* has changed to *Synchronized* or *Attached*.

► Start a circuit-switched connection.

► Open the multi evaluation task.

► Start the multi evaluation task.

8.1 Compensating the External Attenuation

Assume that the DUT provides exactly the right transmitter power at PCL 10 (the current default value). This permits an exact compensation of the external attenuation.

Fig. 8-1 on page 68 shows the current burst power measured by the CMW in the practice setup shown in Fig. 7-1 auf Seite 45.

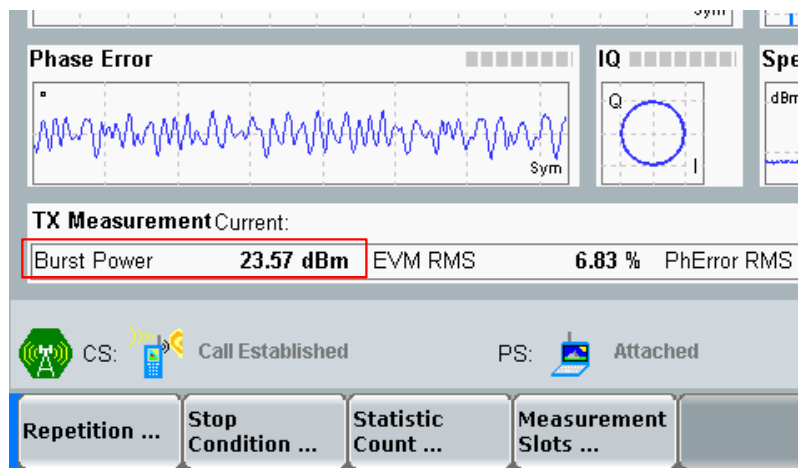In this case, the level deviates from the ideal value of 23 dBm by 0.57 dB.

Fig. 8-1: Burst power, numerical result.

► Open the configuration window for the signaling task (*GSM Signaling, Config*) and correct the external attenuation for the RF input (uplink signal) by the amount of the deviation you identified, see Fig. 8-2.

The TCH/PDCH uplink and downlink use the same cable. Therefore the external attenuation will be the same for the TCH/PDCH RF output.

The uplink and downlink frequencies lie not very far apart. It can therefore be assumed that the same attenuation will apply for the RF output of the BCCH.

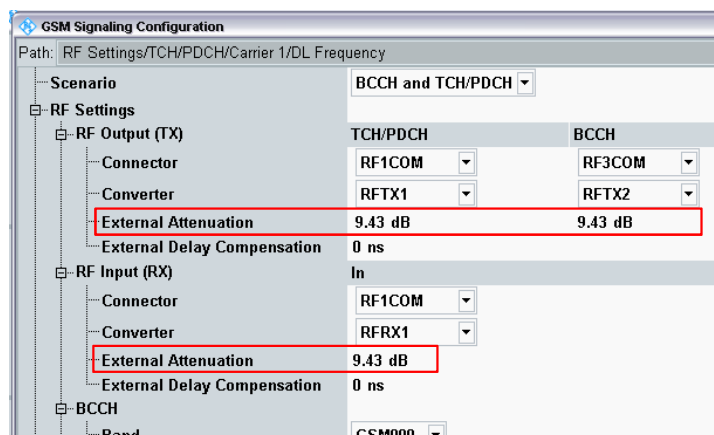► Correct the external attenuation of the two RF outputs accordingly.

Fig. 8-2: Fine-tuning the external attenuation.

► **Save the current CMW configuration as the new basic configuration** *LabConfig.dfl*

The external attenuation for the RF input path could also be set in the configuration window for the multi evaluation task. Is it possible to set the external attenuation for the RF output path there as well? Why or why not?

8.2 Power Versus Time / Circuit Switched

If the circuit-switched connection is no longer established:

► Set up a circuit-switched connection.

► Open the multi evaluation task.

► Start the multi evaluation task.

► Maximize the Power vs. Time window (*Display / Select View / Power vs. Time*).

In addition to the timing information, you will now see a table with the numerical results for all eight slots of a frame.

Timeslot 3 is active. The CMW detects a normal burst (NB) with training sequence (TSC) 0. GMSK is the modulation mode used.

► Zoom the active burst in x- and y-direction (*Display / X-Scale, Y-Scale*).

Which ripple can be identified? Which ripple would theoretically be expected?

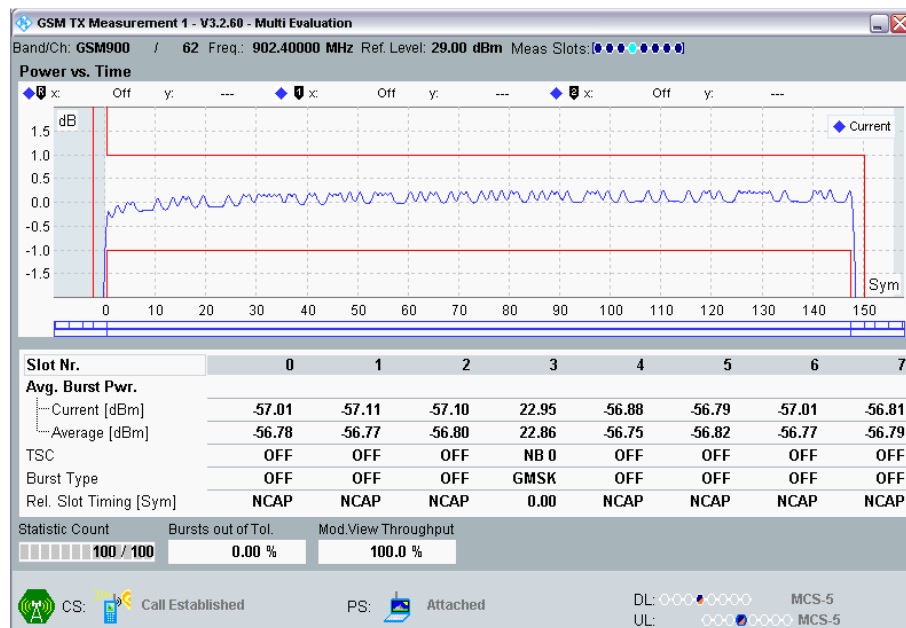What can be seen in the section of the training sequence?

Slot Nr.	0	1	2	3	4	5	6	7
Avg. Burst Pwr.								
Current [dBm]	-57.01	-57.11	-57.10	22.95	-56.88	-56.79	-57.01	-56.81
Average [dBm]	-56.78	-56.77	-56.80	22.86	-56.75	-56.82	-56.77	-56.79
TSC	OFF	OFF	OFF	NB 0	OFF	OFF	OFF	OFF
Burst Type	OFF	OFF	OFF	GMSK	OFF	OFF	OFF	OFF
Rel. Slot Timing [Sym]	NCAP	NCAP	NCAP	0.00	NCAP	NCAP	NCAP	NCAP

Fig. 8-3: CS: power versus time.

► Change the trace displays (*Select Trace...*).

Check what happens when the measurement bandwidth is increased:

► Set the measurement bandwidth to 1 MHz. (*Config* for the Multi Eval. task, *PvT Filter*)

Fig. 8-4: Changing the measurement bandwidth.

How did the identified GMSK ripple come about?

Limits

The horizontal blue bar below the timing display is used to indicate when the upper or lower limit lines are violated. Your DUT will likely respect all limits. These next steps simulate a limit violation.

One way to do this is to starkly restrict the limits (the template) in the configuration window for the multi evaluation task.

However, this exercise uses a different option, by reducing the uplink power.

How is the uplink power for the DUT controlled?

The configuration window for the signaling task controls not only the PCL for the uplink power. In parallel, it also defines the dynamic range of the CMW, see Fig. 8-5 on page 71.

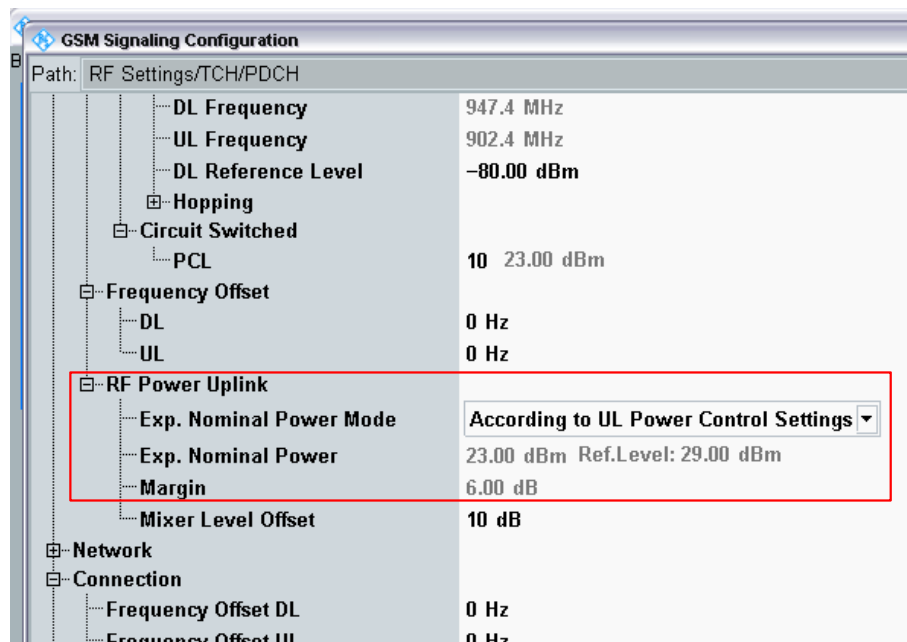The job is to enter the *Expected Nominal Power* at the inputs.

Fig. 8-5: Dynamic range settings for the CMW RX.

With the selection *According to UL Power Control Settings* the CMW assumes as *Expected Nominal Power* exactly the level it instructed the DUT to use (in this case PCL 10 / 23 dBm).

The instrument reserves a *margin* of 6 dB (for GMSK modulation), thus the reference level is set to 29 dBm. This value appears on the screen in the header for each result display.

(Leave the M*ixer Level Offset* setting as default.)

► Set the E*xpected Nominal Power* to M*anual* in the configuration window of the signaling task (*GSM Signaling / Config*).

► Set the power control level *PCL* to 31, see Fig. 8-6 on page 72.

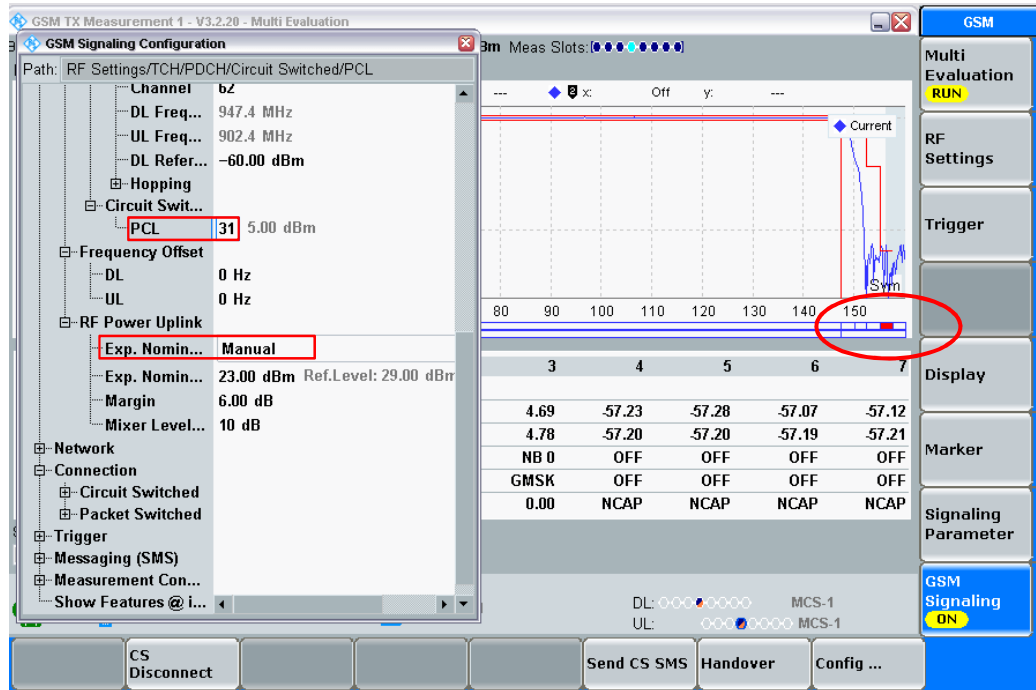What is the power (mW) associated with this level?

Fig. 8-6: Limit violation with the power template.

You should see a violation of the template at the end of the burst. Has the DUT really exceeded the tolerance, or was there a measurement error?

► Set the *Expected Nominal Power* to 5 dBm in the configuration window of the signaling task (*GSM Signaling / Config*).
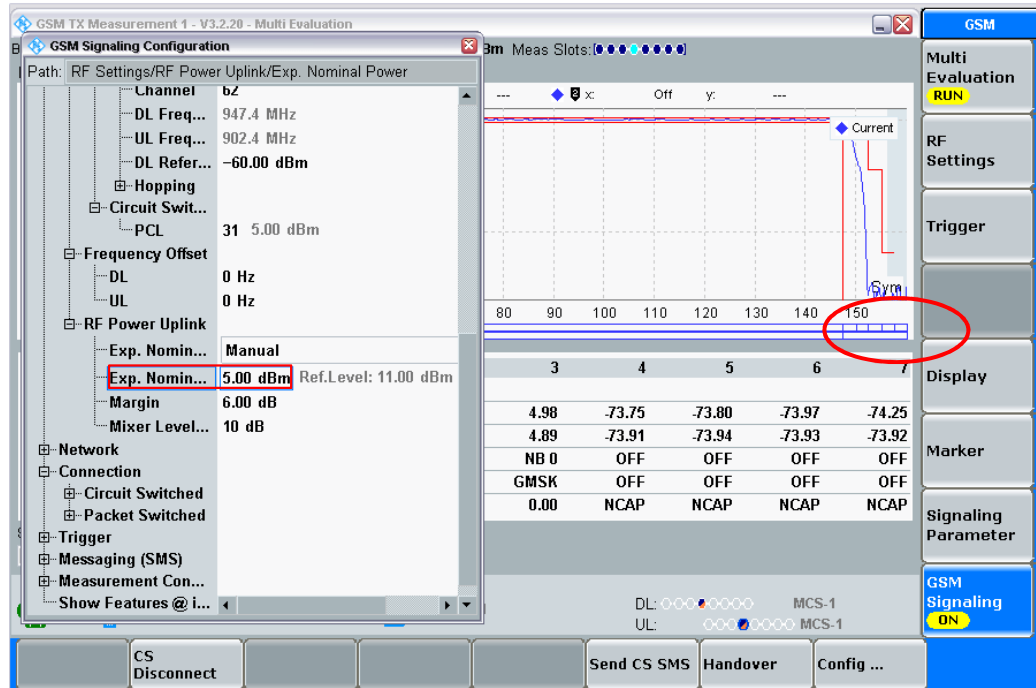

Fig. 8-7: Power versus time with correct setting of the operating range of the CMW receiver.

► Gain some familiarity with the timing display. Observe the additional burst details, for example using Display / Display Areas.

Fig. 8-8: Various display areas.

► Use *CS Disconnect* (GSM signaling task) to end the session.

► Switch off the DUT.

Timing and constellation

► *RESET* the CMW and load the instrument configuration *LabConfig.dfl*

► Open the GSM signaling main view.

► Switch the GSM signaling task on.

Once the connection status for *Circuit Switched* and for *Packet Switched* has changed to *ON*:

► Switch on the DUT and wait until the status for *Circuit Switched* or *Packet Switched* has changed to *Synchronized* or *Attached*.

► Set up circuit-switched connection again.

► Open the multi evaluation task.

► Start the multi evaluation task.

Select the evaluations:

► Under *Assign Views...* select *Power vs. Time* and *IQ*.
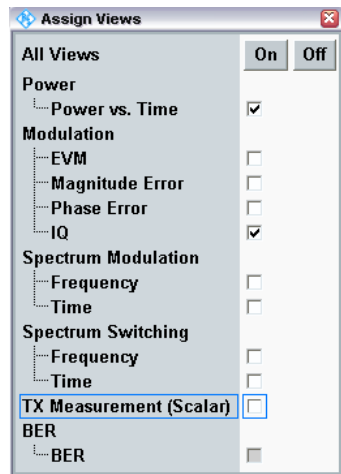
(Clear all other evaluations.)

Fig. 8-9: Evaluation of only two results.

Select which evaluations are to be displayed:

► Under *Display / Select View*, select *Power vs. Time*.

Only *Power vs. Time* will be displayed.

► Under *X-Scale*, set XMax = 160 and XMin = –10.

► Under *Y-Scale*, set YMax = 5 dBm and YMin = –20 dBm.

The scaling option is available only when the screen is reserved exclusively for one result, in this case *power versus time*!

► Under *Display / Select View*, select *Overview*.

Now *Power vs. Time* and *IO* will be displayed. (The scaling option for the timing representation is no longer available.)
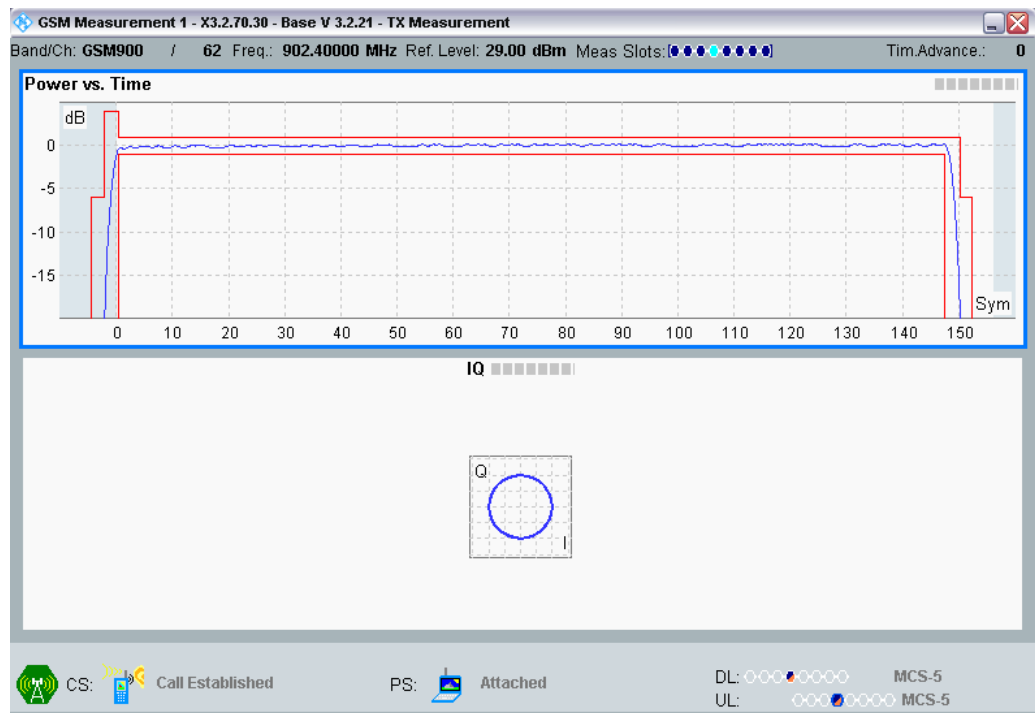
The display should resemble that in Fig. 8-10:

Fig. 8-10: **Combination of power versus time and I/Q (GMSK).**

What type of modulation is being used?

How would a considerable crest factor be seen in the I/Q display?

► End the CS connection.

8.3 Power Versus Time / Packet Switched

Is the connection status still synchronized and attached?

► Start a packet-switched connection.

The display should resemble that in Fig. 8-11:

Fig. 8-11: Combination of power versus time and I/Q / PS.

What changed in the signal as compared with the CS connection?

What changed in the template as compared with the CS connection?

Which type of modulation can be seen?

What burst power was used for the measurement (Gamma is set in the Signaling main view / Connection Setup / Edit)?

► Go to the configuration window for the signaling task and check the *exp. nominal power*.

What margin did the CMW set automatically?

Why?

Are the signal peaks the same size in both the "up" and "down" directions?

MCS-5 with 8-PSK is set for the packet-switched connection configured here. This is used for data transmission.

As for circuit-switched connections using channels SACCH / FACCH, signaling is also interspersed here on the traffic channel using the packet timing control channel PTCCH. This channel is not modulated with 8-PSK, but rather with GMSK! Although the PTCCH seldom appears, it can be detected with the CMW.

In the configuration window for the multi evaluation task, set the display filter *(Modulation View)* to *GMSK*, see Fig. 8-12.
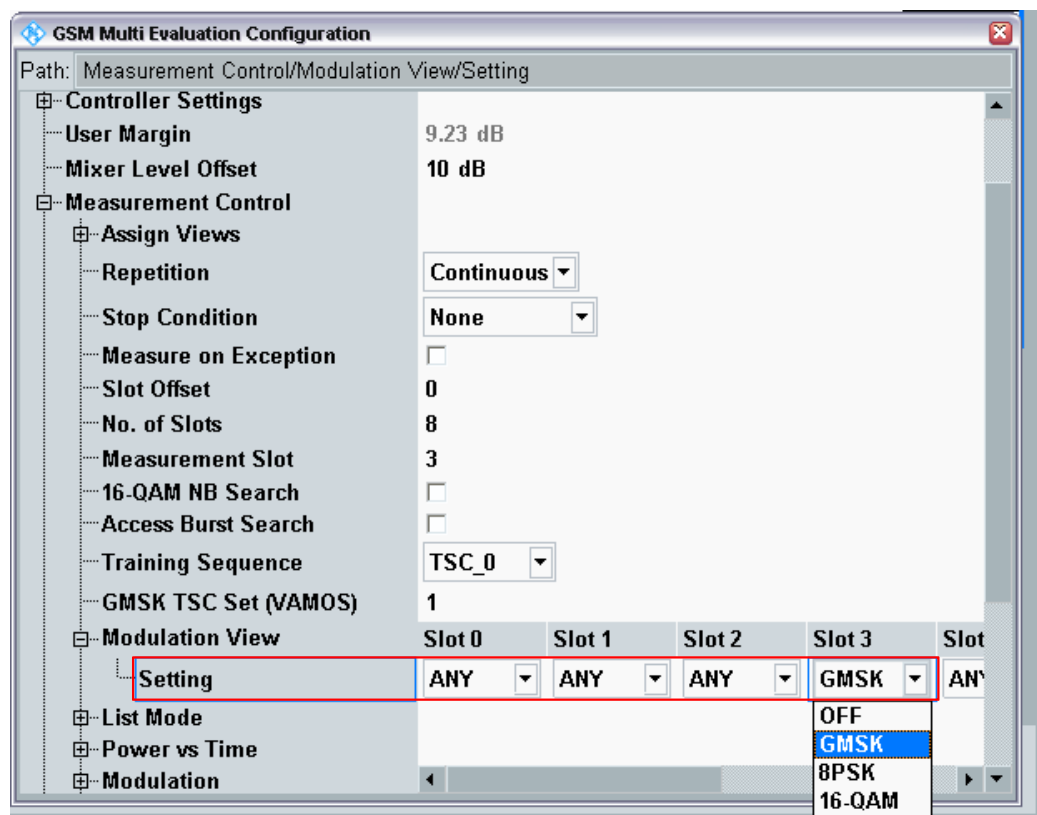

Fig. 8-12: **Selecting the modulation to be filtered.**

Close the configuration window now to see the GMSK burst, see Fig. 8-13 on page 78.

This channel is seldom assigned, which is why the error message *Input Underdriven* flashes continuously.

(The CMW displays measurement results only when a signal is found.)
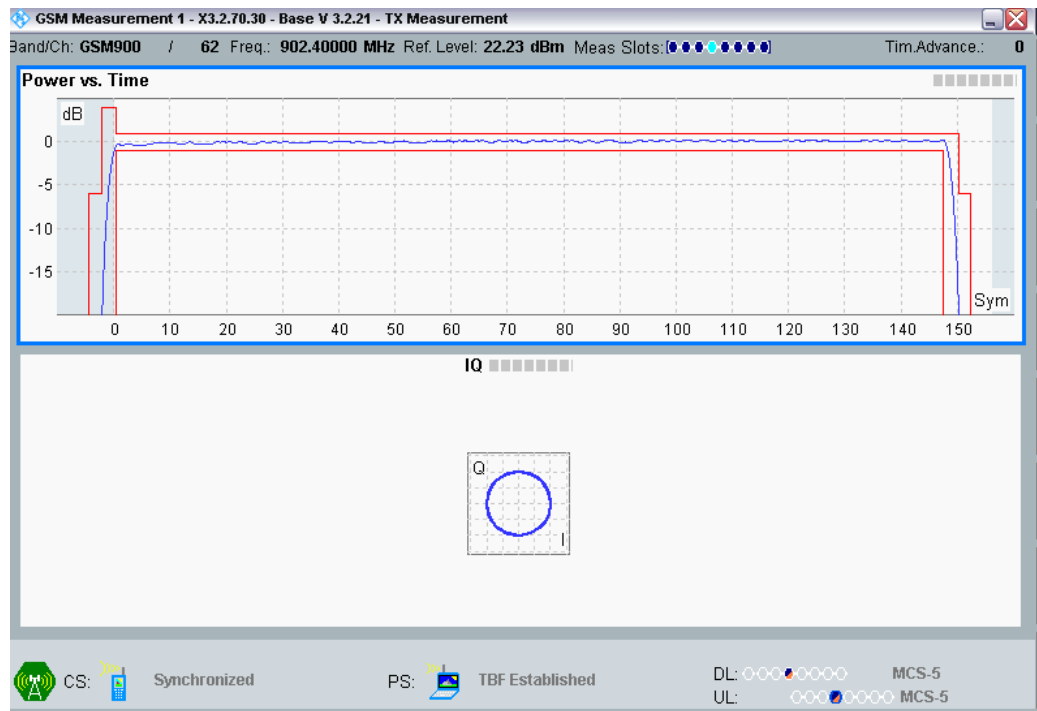
Fig. 8-13: Signaling burst for a PS connection.

Summarize the results of the burst measurements in your own words (the differences between CS / PS with respect to signal waveform and modulation, crest factor, etc.).

9 GSM Measurements: Modulation Quality

The focus of this chapter is on the modulation quality of a mobile phone. The following topics are covered:

▮   Error vector magnitude (EVM)[17]

▮   Magnitude error

▮   Phase error

Each of these uses the deviation of the I/Q vector from the theoretical ideal position. The measurements are made at the CMW in the baseband. Here, the following characteristics can also be determined:

▮   I/Q offset (shift of the constellation diagram from the centered position),

▮   I/Q imbalance (constellation unsymmetries),

▮   Frequency error

▮   Timing error

The purpose of this chapter is to determine whether and how the modulation quality changes when the transmit power varies or when the modulation and coding scheme (MCS) is changed.

Preparation

The DUT should still be switched off.

►   *RESET* the CMW and load the instrument configuration *LabConfig.dfl*.

►   Open the GSM signaling main view.

►   Switch the GSM signaling task on.

Once the connection status for *Circuit Switched* and for *Packet Switched* has switched to *ON*:

►   Switch on the DUT and wait until the *Circuit Switched* or the *Packet Switched* status has changed to *Synchronized* or *Attached*.

►   Set up a circuit-switched connection.

►   Open the multi evaluation task.

►   Start the multi evaluation task.

---

[17] EVM is not defined in the standard for GMSK modulation because of the intersymbol interference (ISI). The CMW therefore first compensates for the ISI and then calculates the EVM as a deviation from the unambiguous endpoints of the I/Q vector rotation.

9.1 Error Vector Magnitude (EVM)

Error vector magnitude (EVM) / circuit switched

► Under *Display / Select View...* select *EVM*.

► Under *Display / Select Trace* select all three traces.

► Adjust the *Y Scale* slightly as needed.

Which PCL is set?
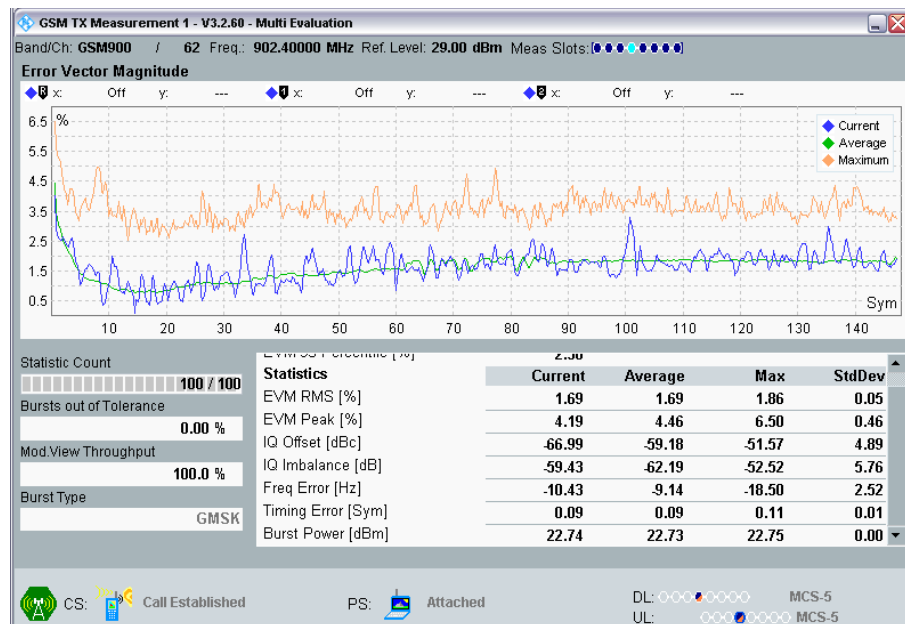
Fig. 9-1 shows typical measurement results:

Fig. 9-1: CS error vector magnitude versus time.

Current (blue) shows the EVM per symbol in the current slot.

Average (green) averages the EVM values per symbol over the number of slots *entered as statistic counts*.

Maximum (orange) identifies the largest EVM value per symbol from the same number of slots.

The EVM in Fig. 9-1 is relatively low. It is largest at the start of the burst, but then decreases and remains fairly constant until the end of the burst.

► Briefly describe the traces.

► Create a table like Table 9-1 on page 81. Enter the *Average* values of the *EVM RMS* and the *EVM Peak* in the column "medium" power.

► Measure at PCL= 0 and PCL = 31, then compare the traces and enter them into the table under the respective RMS and peak values. For PCL=0 use the column "high", for PCL=31 the column "low" power.

Modulation quality			
Power	**low**	**medium**	**high**
CS EVM RMS	2.39 %	1.69 %	1.20 %
CS EVM Peak	4.14 %	4.46 %	3.81 %
PS EVM RMS			
PS EVM Peak			

Table 9-1: CS modulation quality: EVM.

What is your mobile phone's transmit power at PCL = 0? What is the maximum power specified for your mobile phone in the MS capabilities for GSM900 / CS?

Is the midamble recognizable?

Do your measurements show a clear dependency of the EVM on the transmit power?

The mobile phone used for this application note did not show any dependency of the EVM on the transmit power (for a CS connection). The progression of the EVM versus time is also comparable for the three transmit powers (greatest errors at the start). The noisy traces do not show any exceptional peaks.

► End the CS connection. If the DUT loses the PS synchronization (PS status is no longer *attached*), wait until the status *attached* reappears.

Error vector magnitude (EVM) / packet switched

► Set up a packet-switched connection.

► Measure the EVM (using the default value of Gamma = 13).
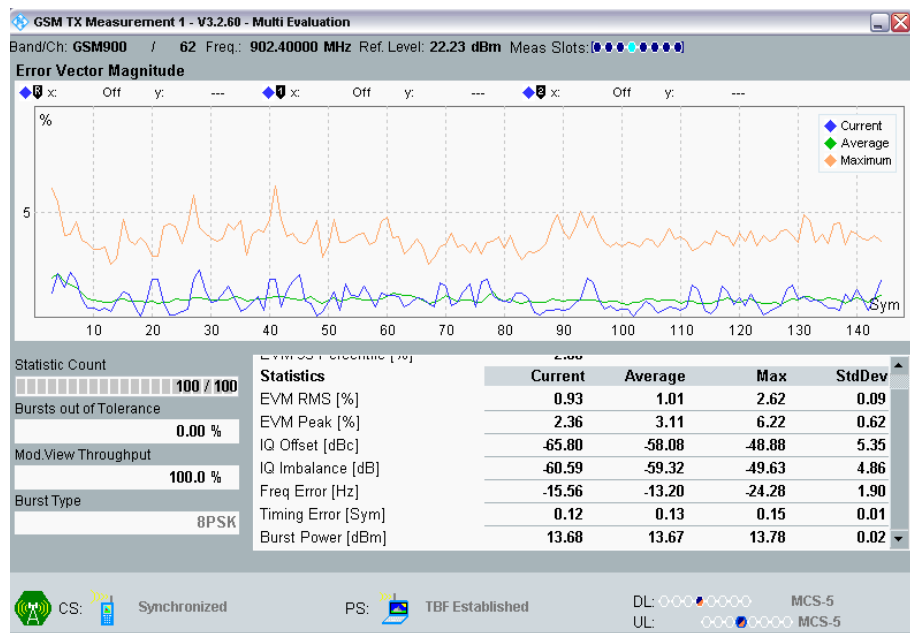
shows typical measurement results:

Fig. 9-2: PS error vector magnitude versus time.

► Give another brief summary of the traces and then enter the *Average RMS* and *Peak* values into your table (Gamma = 13 -> column "medium" power).

► Measure at Gamma = 0 and Gamma = 17, then compare the traces and enter the measurement results into the results table.

Table 9-2 shows typical measurement results:

Modulation Quality			
Power	**low**	**medium**	**high**
CS EVM RMS	2.39 %	1.69 %	1.20 %
CS EVM Peak	4.14 %	4.46 %	3.81 %
PS EVM RMS	0.95 %	1.01 %	1.00 %
PS EVM Peak	2.93 %	3.11 %	3.02 %

Table 9-2: CS and PS modulation quality: EVM.

What is the transmit power for your mobile phone? What is the maximum power specified for your mobile phone in the MS capabilities for GSM900 / PS?

Do your measurements show a clear dependency of the EVM on the transmit power?

The mobile phone used for this application note did not display any dependency of the EVM on the transmit power for a PS connection. The progression of the EVM versus time is also comparable for the three transmit powers (values distributed evenly over the burst).

► Compare the measurement results for CS and PS.

Are there clear differences?

The mobile phone used for this application note showed no clear differences between CS and PS, i.e. between GMSK and 8-PSK modulation. The more noticeable EVM peaks of the 8-PSK bursts could therefore be caused by the fact that certain symbol sequences have larger I/Q variations.

Take another look at the building blocks for the transmission chain in Fig. 9-3.

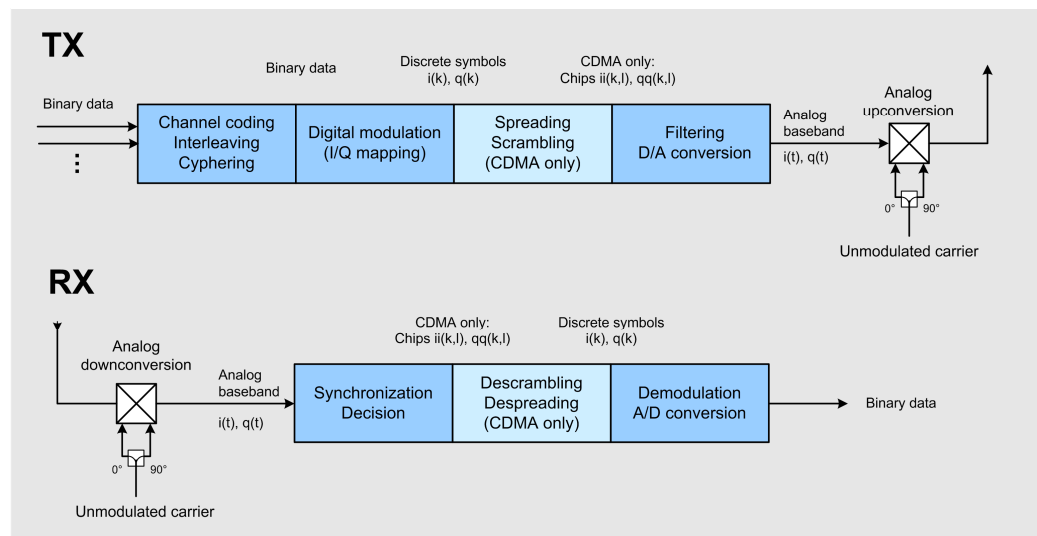Where do the modulation errors originate?

Fig. 9-3: **The mobile radio transmission chain.**

► End the PS connection.

9.2 Magnitude Error

Determine and evaluate the magnitude error in a similar fashion (*Display / Select View.../ Magnitude Error*).

► Measure the CS connection at levels PCL = 0, 10 and 31.

► Evaluate the trace for the three measurements.

► Enter the average values into a table.

Fig. 9-5 shows typical measurement results for circuit switched:
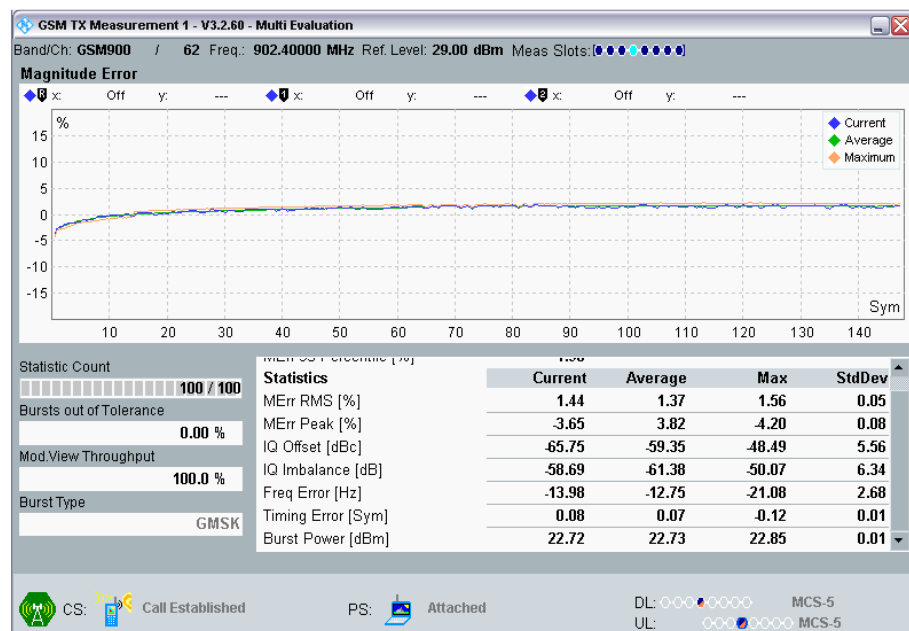

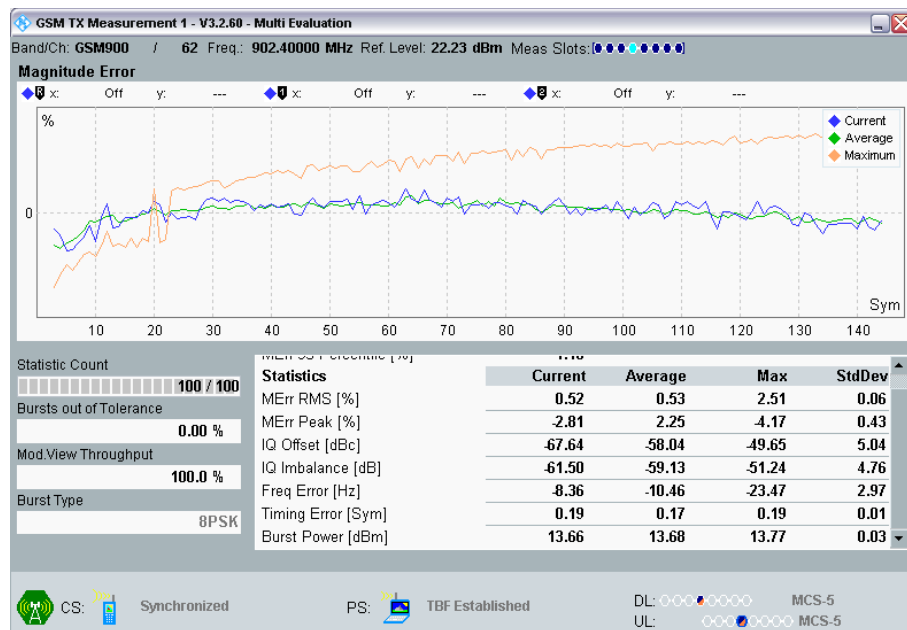**Fig. 9-4: CS modulation quality: Magnitude error.**

► Measure a PS connection with Gamma = 0, 13 and 17.

► Evaluate the trace for the three measurements.

► Enter the average values into a table.

Fig. 9-5: PS modulation quality: Magnitude error.

Table 9-3 shows typical measurement results:

Modulation Quality			
Power	low	medium	high
CS Magn. Error RMS	2.17 %	1.37 %	0.58 %
CS Magn. Error Peak	3.40 %	3.82 %	2.28 %
PS Magn. Error RMS	0.49 %	0.53 %	0.51 %
PS Magn. Error Peak	2.00 %	2.25 %	1.66 %

Table 9-3: CS and PS modulation quality: Magnitude error.

How would you interpret your measurement results? Is there a clear dependency of the magnitude error on the transmit power or modulation?

9.3 Additional Baseband Characteristics

Determine and evaluate the phase error in a similar fashion (*Display / Select View... / Phase Error*), along with other characteristics identified in the baseband:

► Measure the Phase Error for a CS connection at levels PCL = 0, 10 and 31.

► Evaluate the trace for the three measurements.

► Enter the average values into a table.

► Enter into the same table also the average values of

  ▪ I/Q offset

  ▪ I/Q imbalance

  ▪ Frequency error

  ▪ Timing error

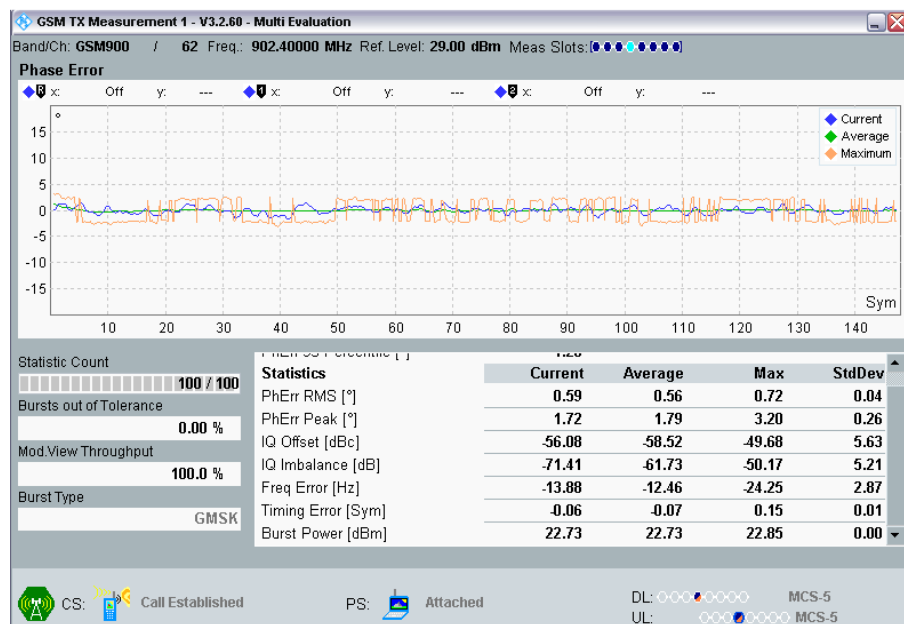Fig. 9-6 shows typical measurement results for circuit switched:

Fig. 9-6: CS phase error versus time.

► Measure a PS connection with Gamma = 0, 13 and 17.

► Evaluate the trace for the three measurements.

► Enter the average values into a table.

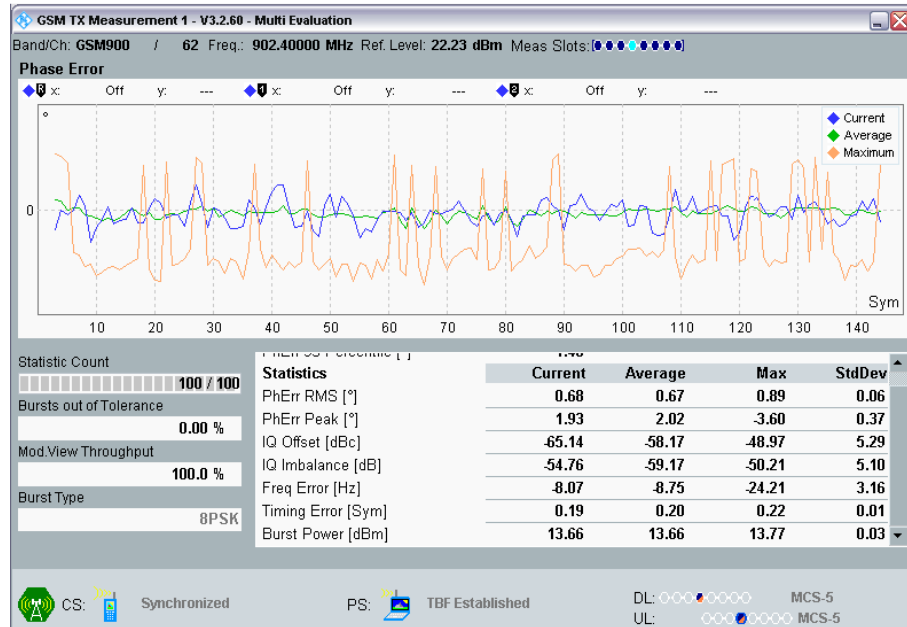Fig. 9-7 shows typical measurement results for packet switched:

Fig. 9-7: PS phase error versus time.

Table 9-4 shows typical measurement results:

Modulation Quality			
Power	**low**	**medium**	**high**
CS Phase Error RMS	0.57 °	0.56 °	0.59 °
CS Phase Error Peak	1.79 °	1.79 °	1.97 °
CS I/Q Offset	–59.16 dBc	–58.52 dBc	–59.13 dBc
CS I/Q Imbalance	–60.15 dB	–61.73 dB	–63.19 dB
CS Freq Error	–11.49 Hz	–12.46 Hz	–14.40 Hz
CS Timing Error	–0.05 Sym.	–0.07 Sym.	–0.20 Sym.
PS Phase Error RMS	0.58 °	0.67 °	0.65 °
PS Phase Error Peak	1.74 °	2.02 °	1.93 °
PS I/Q Offset	–57.42 dBc	–58.17 dBc	–56.86 dBc
PS I/Q Imbalance	–59.61 dB	–59.17 dB	–60.28 dB
PS Freq Error	–8.43 Hz	–8.75 Hz	–7.55 Hz
PS Timing Error	–0.23 Sym.	0.20 Sym.	0.23 Sym.

Table 9-4: Modulation quality overview.

For the mobile phone used in this application note, no dependency of the modulation quality on the transmit power was detected for either a CS or a PS connection. Similarly, the modulation quality is almost independent of whether a GMSK or an 8-PSK signal was measured.

The RF output stage of the mobile phone used here appears to be sufficiently linear to deliver the crest factor of the 8-PSK signal without distortion.

How would you interpret your measurement results? Is there a clear dependency of the phase error on the transmit power or modulation?

Are there any clear dependencies of the other I/Q characteristics on the transmit power or modulation?

How can this be explained?

If a graphical display is not needed, the view found under *Display / Select View... / TX Measurement Scalar* provides a complete overview with all numerical results.
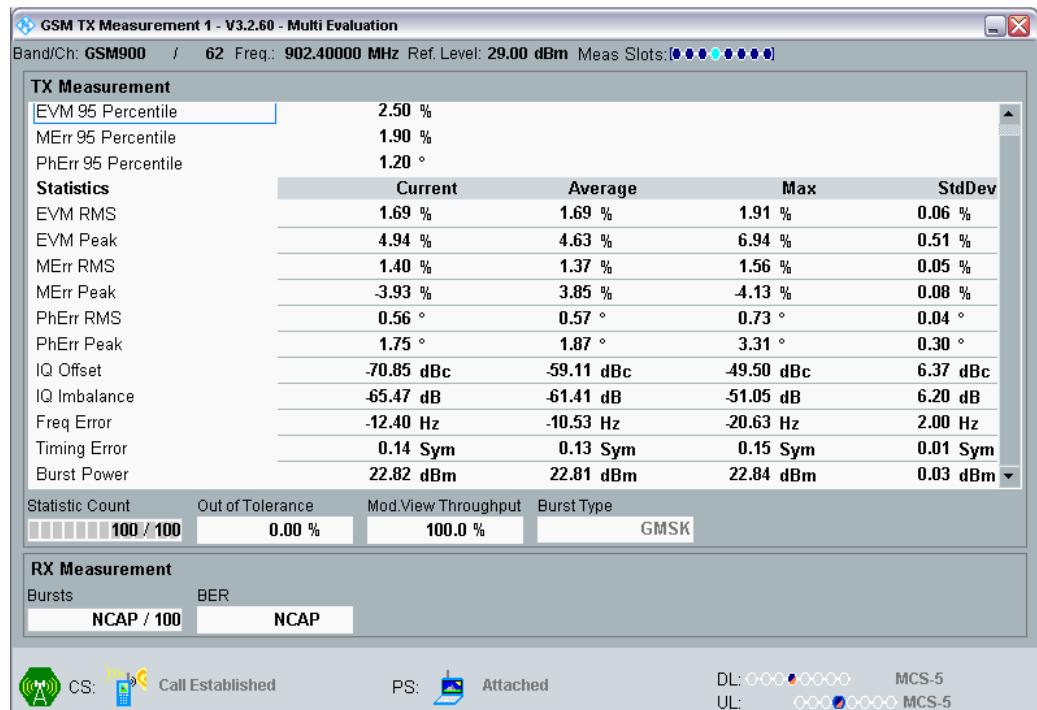
For CS, this display resemble that in Fig. 9-8.

TX Measurement	Current	Average	Max	StdDev
EVM 95 Percentile	2.50 %			
MErr 95 Percentile	1.90 %			
PhErr 95 Percentile	1.20 °			
Statistics	**Current**	**Average**	**Max**	**StdDev**
EVM RMS	1.69 %	1.69 %	1.91 %	0.06 %
EVM Peak	4.94 %	4.63 %	6.94 %	0.51 %
MErr RMS	1.40 %	1.37 %	1.56 %	0.05 %
MErr Peak	-3.93 %	3.85 %	-4.13 %	0.08 %
PhErr RMS	0.56 °	0.57 °	0.73 °	0.04 °
PhErr Peak	1.75 °	1.87 °	3.31 °	0.30 °
IQ Offset	-70.85 dBc	-59.11 dBc	-49.50 dBc	6.37 dBc
IQ Imbalance	-65.47 dB	-61.41 dB	-51.05 dB	6.20 dB
Freq Error	-12.40 Hz	-10.53 Hz	-20.63 Hz	2.00 Hz
Timing Error	0.14 Sym	0.13 Sym	0.15 Sym	0.01 Sym
Burst Power	22.82 dBm	22.81 dBm	22.84 dBm	0.03 dBm

Fig. 9-8: CS: All baseband results at a glance.

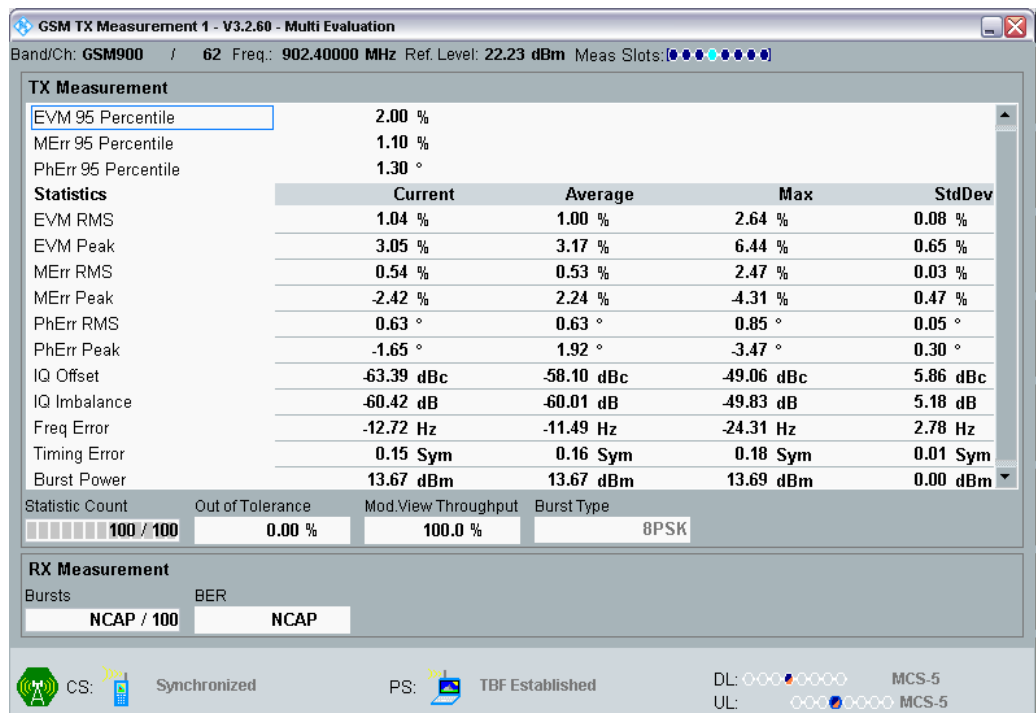For PS, the following overview was obtained for the DUT used:

Fig. 9-9: PS: All baseband results at a glance.

Summarize the results of your measurements in your own words.

10 GSM Measurements: Frequency Spectrum

The focus of this chapter is on determining the emissions from a mobile phone in the frequency domain. The goal is to become familiar with the special measurement procedures and to gain "a feel" for how the emissions arise.

The spectrum of a GSM signal is created by

▪ the modulation and

▪ the rising and falling burst edges.

Standard 3GPP TS 11.10 separates these two effects and measures them independently as spectrum due to modulation (DTM) and spectrum due to switching (DTS). In both measurements, the spectrum is not checked continuously, but rather only at a few discrete frequency offsets. This shortens the test time considerably.

(The few frequencies that are checked make this test appear to be not particularly stringent. In addition, a great number of limit violations is permitted.)

The spectrum due to modulation measures only within a time window that is 40 to 45 symbols long within the useful part of the active burst. An average is formed over a number of measurements. The DTM shows whether the (baseband) filtering is implemented correctly.

The spectrum DTS, on the other hand, runs for the entire duration of the **slot** and the result includes all spectral components of the transmit signal occurring during that time. So, this measures the total interference in the adjacent channels. The peak value from a number of measurements is taken as the result. It is assumed that the measured powers originate primarily from the burst edges and that the acquired spectrum due to modulation components will not contribute significantly.

In contrast to a true power measurement with the (signal) bandwidth of about 300 kHz, a 30 kHz filter is used for DTM and DTS. Of course, this comprises only a portion of the signal power. The R*ef Power* displayed on the CMW at frequency offset 0 therefore is about 8 dB lower than the actual total burst power for DTM and GMSK modulation. In the case of DTS and 8-PSK, the signal crest factor and the peak detector being used result in a *Ref Power* that is slightly higher than the actual burst power.

The following measurements are specified, each at a low and a high level:

11.1 Spectrum DTM, circuit switched

11.2 Spectrum DTM, packet switched

11.3 Spectrum DTS, circuit switched

11.4 Spectrum DTS, packet switched

To permit a comparison with a PS connection, the CS measurement does not use the maximum CS level, but rather the lower maximum PS level (27 dBm).

Preparation

The DUT should still be switched off.

► *RESET* the CMW and load the instrument configuration *LabConfig.dfl*.

► Open the GSM signaling main view.

► Switch the GSM signaling task on.

Once the connection status for *Circuit Switched* and for *Packet Switched* has changed to *ON*:

► Switch on the DUT and wait until the *Circuit Switched* or the *Packet Switched* status has changed to *Synchronized* or *Attached*.

10.1 Spectrum Due to Modulation / Circuit Switched

1a. DTM / Circuit Switched / 27 dBm

► In the signaling main view, set a CS uplink level of 27 dBm. (*Connection Setup, Edit, Slot 3 (CS) PCL=..., ESC*)

► Set up a circuit-switched connection.

► Open the multi evaluation task.

(Select all measurements under *Assign Views.*)

► Start the multi evaluation task.

► Under *Display / Select View...* select *Spectrum Modulation Freq.*

The resulting display is similar to that in Fig. 10-1 on page 92. You can see the discrete measurement frequencies defined by the standard, the readings and the limits marked in red. (The defaults used here are the limit values from the standard. However, you can skip some test points and define others in their place. This can be useful in order to scale the graphical display differently.)

Which "main topic" is the current horizontal softkey bar associated with?

Note: A CS connection uses GMSK modulation. Ideally, this is a true phase modulation without changes in the amplitude. The spectrum DTM is therefore symmetrical.

Use the *Time Curve Off / ON* in the Display softkey bar to open a time display of the power at a specific frequency sample point. This is done later for the spectrum due to switching measurements.
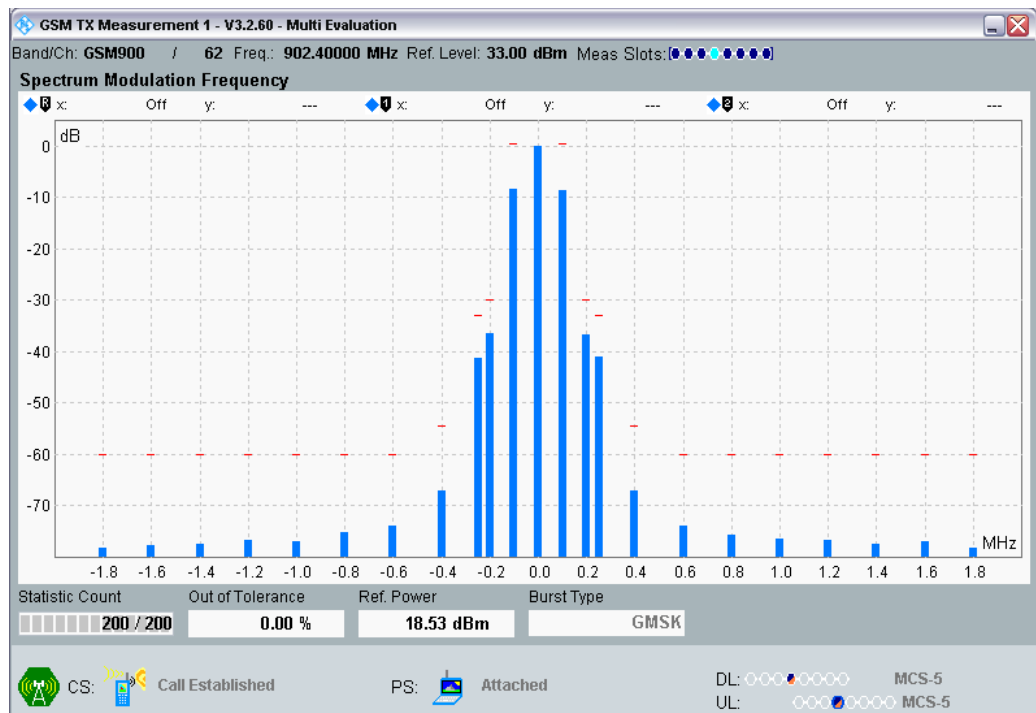
Fig. 10-1: CS spectrum DTM / 27 dBm.

The "Marker" softkey in the vertical softkey bar is used to open the individual test points in the graphical display and to read the scalar values.

► From the Display softkey bar, switch from *Diagram View* to *Fig. View*. The display should resemble that in Fig. 10-2:

All scalar measurement results are displayed here. These are relative to the R*ef. Power*, i.e. the power at frequency offset = 0 (measured with a 30 kHz bandwidth).
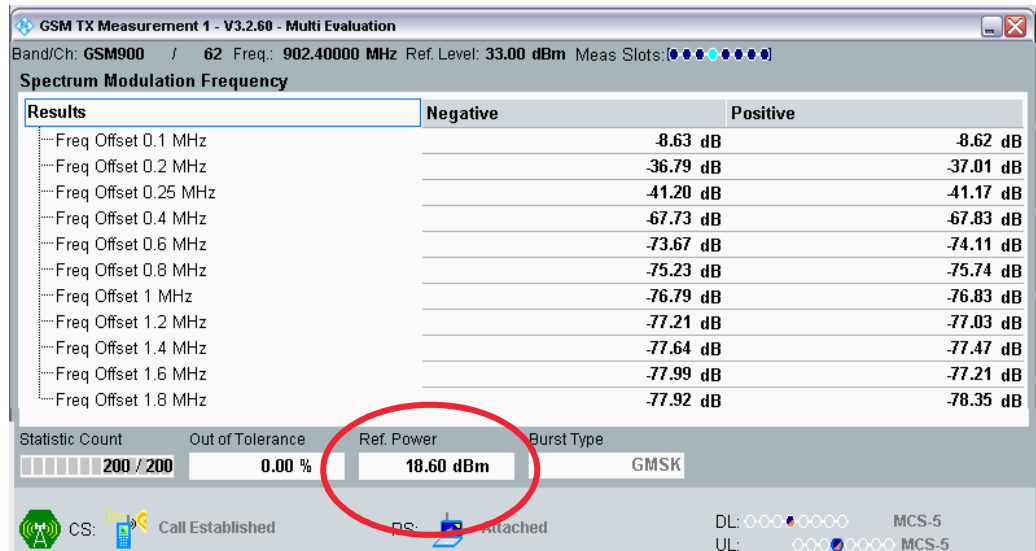

Fig. 10-2: CS spectrum DTM / 27 dBm.

► In the softkey bar to the right, press Multi Evaluation again.

Which "main topic" is the current horizontal softkey bar associated with?

To perform a single measurement with stable results:

► Use the softkey *Repetition* to switch the CMW to *Single Shot*.

A new single measurement can be started with the hardkey RESTART / STOP (or by pressing *ON / OFF* twice).

► Make a note of the measurement results from one of the two columns (e.g. the neg. frequency offset).

Are the components for positive and negative frequency offsets almost the same? Why is this?

Is it possible to see a relationship between the defined measurement frequencies and the GSM channel spacing?

1b. DTM / Circuit Switched / 5 dBm

► Set the CS uplink level to 5 dBm. This time, make the settings in the configuration window for the signaling task instead (*Config, RF-Settings, TCH/PDCH, Circuit Switched, PCL=..., ESC*). In the softkey bar to the right, press Multi Evaluation again.

► Start a new single measurement with the hardkey *RESTART / STOP*.

► Make a note of the *Ref. Power*.

► Compare the measurement results against those taken at 27 dBm (several tenths of a dB difference can be ignored, especially at very low levels).

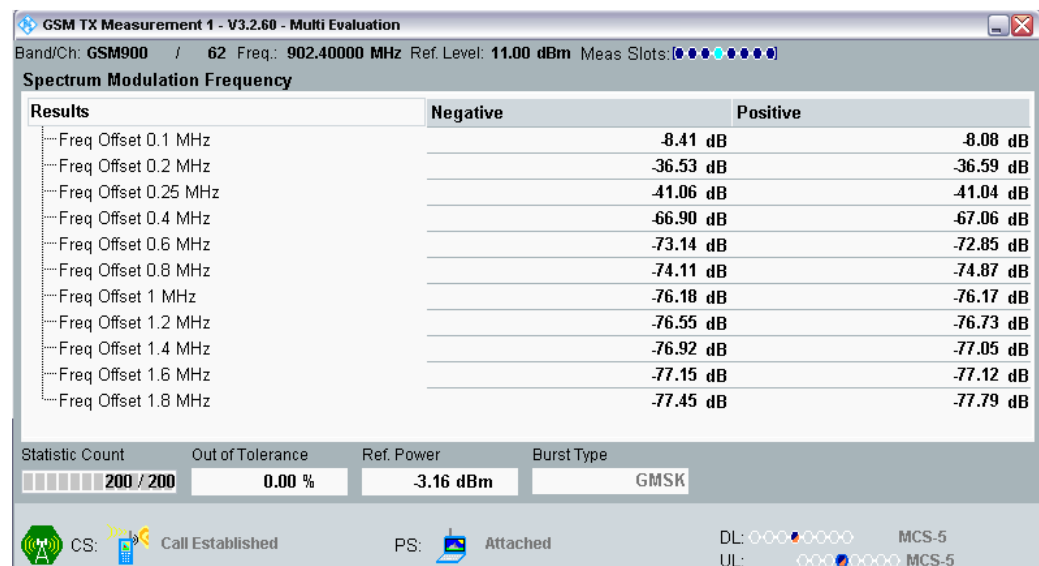Fig. 10-3 shows the results from the phone used for this application note.

| GSM TX Measurement 1 - V3.2.60 - Multi Evaluation			
Band/Ch: GSM900 / 62 Freq.: 902.40000 MHz Ref. Level: 11.00 dBm Meas Slots:[●●●●○●●●●]			
Spectrum Modulation Frequency			
Results		**Negative**	**Positive**
Freq Offset 0.1 MHz		-8.41 dB	-8.08 dB
Freq Offset 0.2 MHz		-36.53 dB	-36.59 dB
Freq Offset 0.25 MHz		-41.06 dB	-41.04 dB
Freq Offset 0.4 MHz		-66.90 dB	-67.06 dB
Freq Offset 0.6 MHz		-73.14 dB	-72.85 dB
Freq Offset 0.8 MHz		-74.11 dB	-74.87 dB
Freq Offset 1 MHz		-76.18 dB	-76.17 dB
Freq Offset 1.2 MHz		-76.55 dB	-76.73 dB
Freq Offset 1.4 MHz		-76.92 dB	-77.05 dB
Freq Offset 1.6 MHz		-77.15 dB	-77.12 dB
Freq Offset 1.8 MHz		-77.45 dB	-77.79 dB

Statistic Count	Out of Tolerance	Ref. Power	Burst Type
200 / 200	0.00 %	-3.16 dBm	GMSK

CS: Call Established   PS: Attached   DL: ○○○●○○○○ MCS-5   UL: ○○○●○○○○ MCS-5

Fig. 10-3: CS spectrum DTM / 5 dBm.

Are the spectra DTM for GMSK listed here proportional to the transmit power?

Is the same true for your measurement results?

Does it make sense to define the limits for DTM as relative values?

► End the CS connection.

10.2 Spectrum Due to Modulation / Packet Switched

2a. DTM / Packet Switched / 27 dBm

► In the signaling main view, set a PS uplink level of 27 dBm. (*Connection Setup, Edit, Slot 3, Gamma =..., ESC*)

► Set up a packet-switched connection.

► Open the multi evaluation task.

► Start the multi evaluation task.

► Start a new single measurement with the hardkey *RESTART / STOP*.

► Under *Display / Diagram View... select the graphical display again.*

You will see a spectrum similar to that in Fig. 10-4 on page 95.

Note: The modulation and coding scheme MSC-5 used in this application note for PS works with 8-PSK. It therefore includes components of both an amplitude and a phase modulation which in sum partly enlarge or diminish each other. As a result, the spectrum DTM is unsymmetrical.
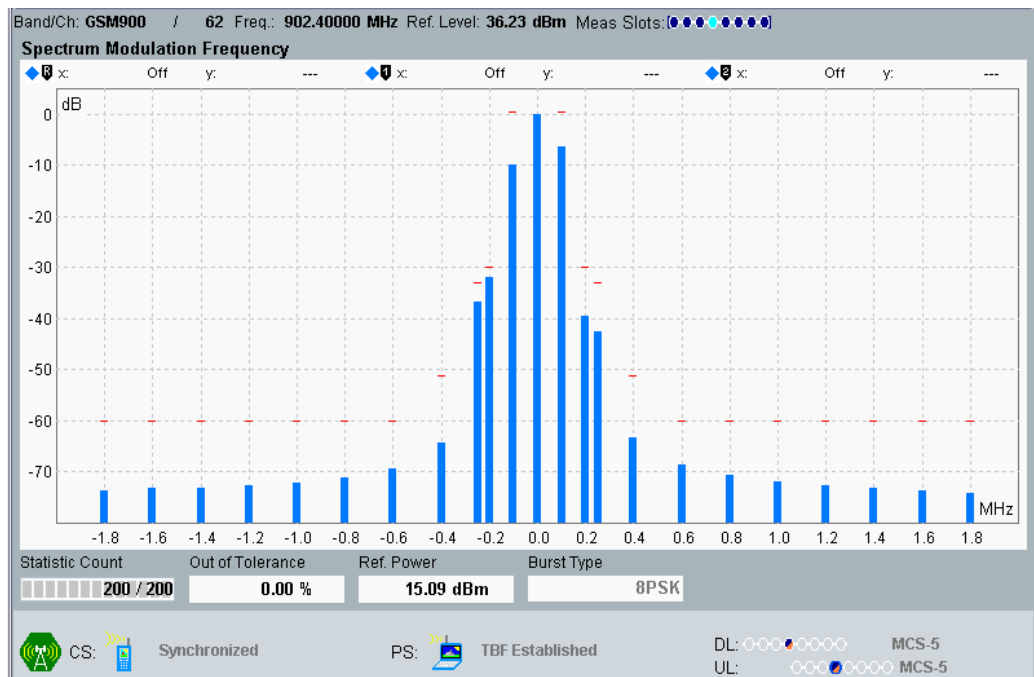
Fig. 10-4: PS spectrum DTM / 27 dBm.

Are the emissions greater than those from the circuit-switched measurement with GMSK modulation?

Why?

► From the Display softkey bar, switch from *Diagram View* to *Fig. View*. The display should resemble that in Fig. 10-5:
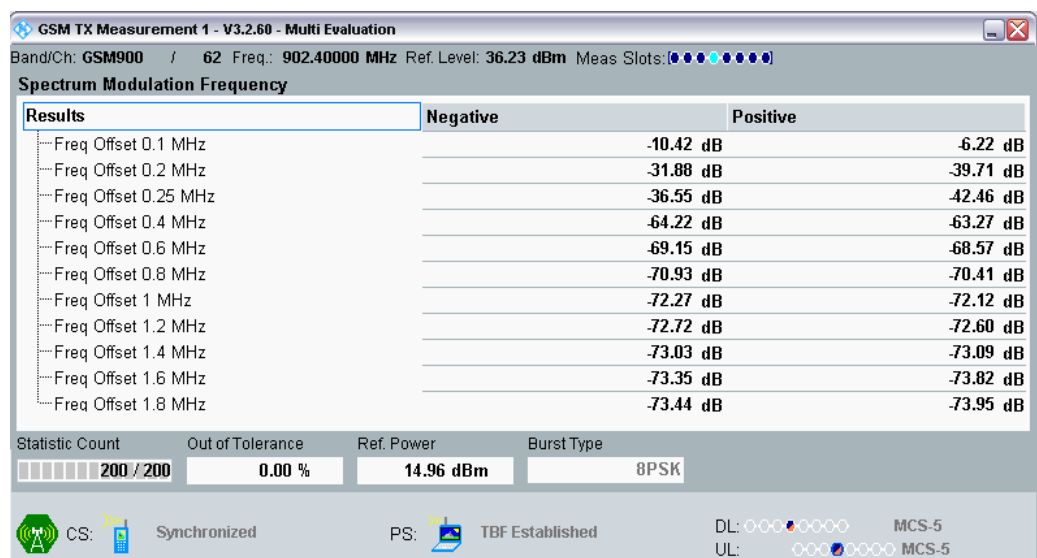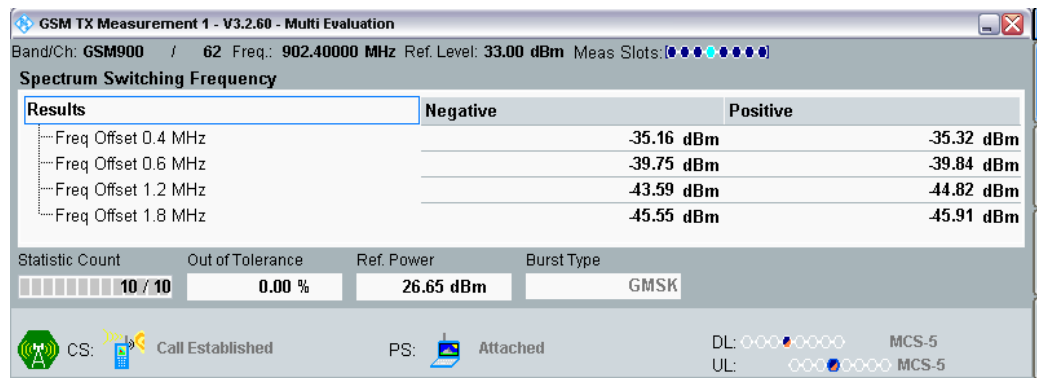

Fig. 10-5: PS spectrum DTM / 27 dBm.

► Make a note of the measurement results from one of the two columns (e.g. the neg. frequency offset).

Are the components for positive and negative frequency offsets close to the same?

Why is this?

2b. Spectrum Due to Modulation / Packet Switched / 5 dBm

► Set a PS uplink level of 5 dBm. In the softkey bar to the right, press Multi Evaluation again.

► Start a new single measurement with the hardkey *RESTART / STOP*.

► Make a note of the Ref. Power.

► Compare the current measurement results against those taken at 27 dBm (several tenths of a dB difference can be ignored).

Are the spectra DTM for 8-PSK also proportional to the transmit power?

► End the CS connection (*CS Disconnect* in the signaling task).

Describe in your own words what is the same for DTM with CS and PS, and what is different.

How is the spectrum DTM formed?

10.3 Spectrum Due to Switching / Circuit Switched

3a. DTS / Circuit Switched / 27 dBm

The spectrum DTS is a measure of all relevant spectral components occurring in the transmit signal. In particular, it measures the degree of interference in the adjacent channels.

► Set a CS uplink level of 27 dBm.

► Set up a circuit-switched connection.

► Open the multi evaluation task.

► Start the multi evaluation task.

► Under *Display / Select View...* select *Spectrum Switching Freq.*

You will see a spectrum similar to that in .

Fig. 10-6: CS spectrum DTS / 27 dBm.

The display shows the discrete test points defined by the standard in the spectrum, the readings and the limits in red.

In contrast to spectrum due to modulation, absolute power is measured here. The Table 10-1 shows the limits for GSM900 and the different uplink levels:

Power level	Maximum level for various offsets from carrier frequency			
	400 kHz	600 kHz	1 200 kHz	1 800 kHz
39 dBm	-13 dBm	-21 dBm	-21 dBm	-24 dBm
37 dBm	-15 dBm	-21 dBm	-21 dBm	-24 dBm
35 dBm	-17 dBm	-21 dBm	-21 dBm	-24 dBm
33 dBm	-19 dBm	-21 dBm	-21 dBm	-24 dBm
31 dBm	-21 dBm	-23 dBm	-23 dBm	-26 dBm
29 dBm	-23 dBm	-25 dBm	-25 dBm	-28 dBm
27 dBm	-23 dBm	-26 dBm	-27 dBm	-30 dBm
25 dBm	-23 dBm	-26 dBm	-29 dBm	-32 dBm
23 dBm	-23 dBm	-26 dBm	-31 dBm	-34 dBm
<= +21 dBm	-23 dBm	-26 dBm	-32 dBm	-36 dBm

Table 10-1: GSM spectrum limits DTS.

► From the Display softkey bar, switch from *Diagram View* to *Fig. View*. The display will resemble that in Fig. 10-7 on page 98.

Fig. 10-7: CS spectrum DTS / 27 dBm.

► Make a note of the measurement results from one of the two columns (e.g. the neg. frequency offset).

Are the components for positive and negative frequency offsets close to the same?

Why is this?

3b. DTS / Circuit Switched / 5 dBm

► Set a CS uplink level of 5 dBm. In the softkey bar to the right, press Multi Evaluation again.

► Start a new single measurement with the hardkey *RESTART / STOP*.
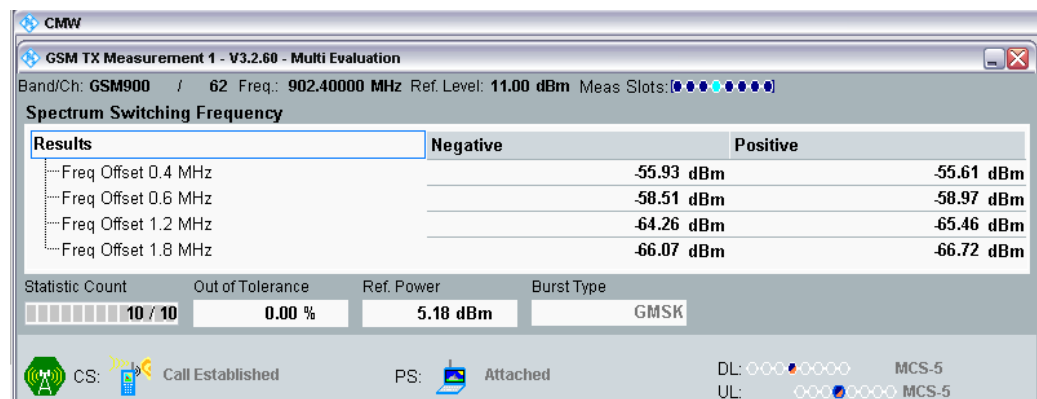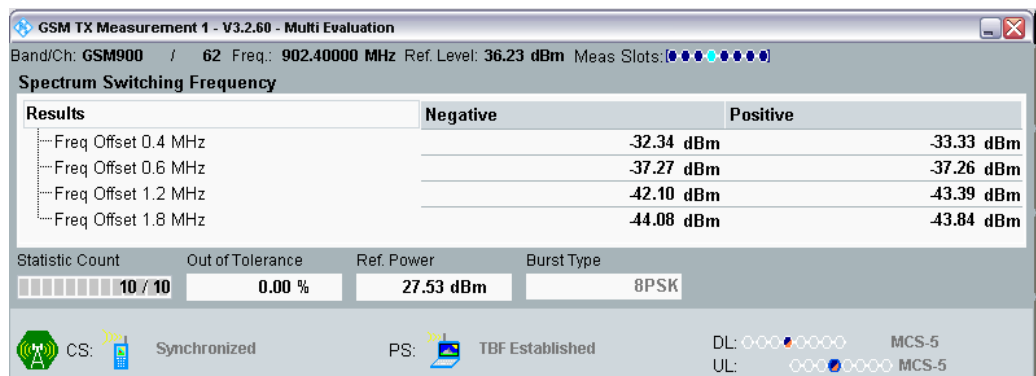
The results should resemble those in Fig. 10-8:

Fig. 10-8: CS spectrum DTS / 5 dBm.

► Calculate the difference d between the two ref. powers (DTS, CS). In this case, d = 21.5 dB.

► Subtract this difference from the corresponding measurement result at 27 dBm, as shown in the Table 10-2 with the results from this application note.

► Compare the new values against those taken at 5 dBm (several tenths of a dB difference can be ignored).

Comparison of DTS @ 27 dBm and DTS @ 5 dBm / CS Connection		
Freq. Offset	**DTS @ 27 dBm – d**	**DTS @ 5 dBm**
0.4 MHz	−35.16 dBm − 21.5 dB = −56.66 dBm	−55.93 dBm
0.6 MHz	−39.75 dBm − 21.5 dB = −61.25 dBm	−58.51 dBm
1.2 MHz	−43.59 dBm − 21.5 dB = −65.09 dBm	−64.26 dBm
1.8 MHz	−45.55 dBm − 21.5 dB = −67.05 dBm	−66.07 dBm

Table 10-2: Comparison of the two levels.

In this case, the results do not appear to be directly proportional to the transmit power.

Is the same true for your measurement results?

► End the CS connection (*CS Disconnect* in the signaling task).

10.4 Spectrum Due to Switching / Packet Switched

4a. DTS / Packet Switched / 27 dBm

► In the signaling main view, set a PS uplink level of 27 dBm.

► Set up a packet-switched connection (*PS Connect*).

► Open the multi evaluation task.

(Select all measurements under *Assign Views.*)

► Start the multi evaluation task.

► Start a new single measurement with the hardkey *RESTART / STOP*.

► Under *Display / Diagram View... select the graphical display again.*

The spectrum will resemble that in Fig. 10-9 on page 100.

Fig. 10-9: PS spectrum DTS / 27 dBm.

► From the Display softkey bar, switch from *Diagram View* to *Fig. View*. The display should resemble that in Fig. 10-10:

►

Fig. 10-10: PS spectrum DTS / 27 dBm.

Are the emissions greater than those from the GMSK modulation? (Don't forget the detector...)

Is the spectrum approximately symmetrical?

Why is this?

► Make a note of the measurement results from one of the two columns (e.g. the neg. frequency offset).

4b. DTS / Packet Switched / 5 dBm

► Set a PS uplink level of 5 dBm. In the softkey bar to the right, press Multi Evaluation again.

► Start a new single measurement with the hardkey *RESTART / STOP*.

The results should resemble those in Fig. 10-11:
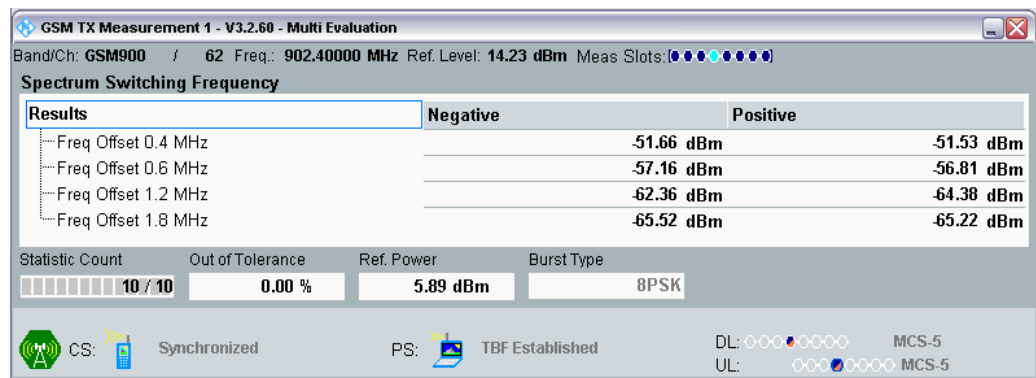
Fig. 10-11: PS spectrum DTS / 5 dBm.

► Calculate the difference d between the two ref. powers (DTS, PS). Here again, d = 21.5 dB approximately.

► Subtract this difference from the corresponding measurement result at 27 dBm, as shown in the Table 10-3 with the results from this application note.

► Compare the new values against those taken at 5 dBm (several tenths of a dB difference can be ignored).

Comparison of DTS @ 27 dBm and DTS @ 5 dBm / PS Connection		
Freq. Offset	**DTS @ 27 dBm – d**	**DTS @ 5 dBm**
0.4 MHz	−32.34 dBm − 21.5 dB = −53.84 dBm	−51.66 dBm
0.6 MHz	−37.27 dBm − 21.5 dB = −58.77 dBm	−57.16 dBm
1.2 MHz	−42.10 dBm − 21.5 dB = −63.60 dBm	−62.36 dBm
1.8 MHz	−44.08 dBm − 21.5 dB = −65.58 dBm	−65.52 dBm

Table 10-3: Comparison of the two levels.

In this case, the spectrum is similar, but the results are not directly proportional to the transmit power.

Is the same true for your measurement results?

Describe in your own words what is the same for DTS with CS and PS, and what is different.

Origin of the components in the spectrum DTS

If the spectrum DTS were defined only by the burst edges, then CS and PS would have the same spectrum.

► Compare the measurement results for CS and PS with DTS and 5 dBm level.

Are the spectra the same?

To determine the components of the spectrum DTS, the power vs. time at the various test frequencies will be analysed.

► Select *Display / Select View... / Diagram View*.

► Set *Time Curve On*.

A second screen opens with a timing display; see page.

► In the softkey bar to the right, select *Multi Evaluation* again.

► Set *Repetition* to *Continuous*.

► Start the continuous measurement.

► In the horizontal softkey bar, press *Frequency Offsets*.

This displays the list of the current *freq. offsets*; at present, these are the default offset frequencies for GSM. Use the –4 to +4 indices to select the test points in the spectrum display. (You can edit this table, for example expand it as needed.)

Fig. 10-12: Table of frequency offsets for the spectrum measurements.

► Close the window.

► In the horizontal softkey bar, select *Time Dom, @ Freq. Select...*

► Observe the power vs. time for the indices –4 to +4.

On the mobile phone used for this application note, the contribution of the modulation (during the burst) clearly predominates for the offsets +/– 400 kHz (Fig. 10-13). Only for Offsets from offsets +/– 600 kHz the contribution of the burst ramping becomes significant (Fig. 10-14 on page 104).
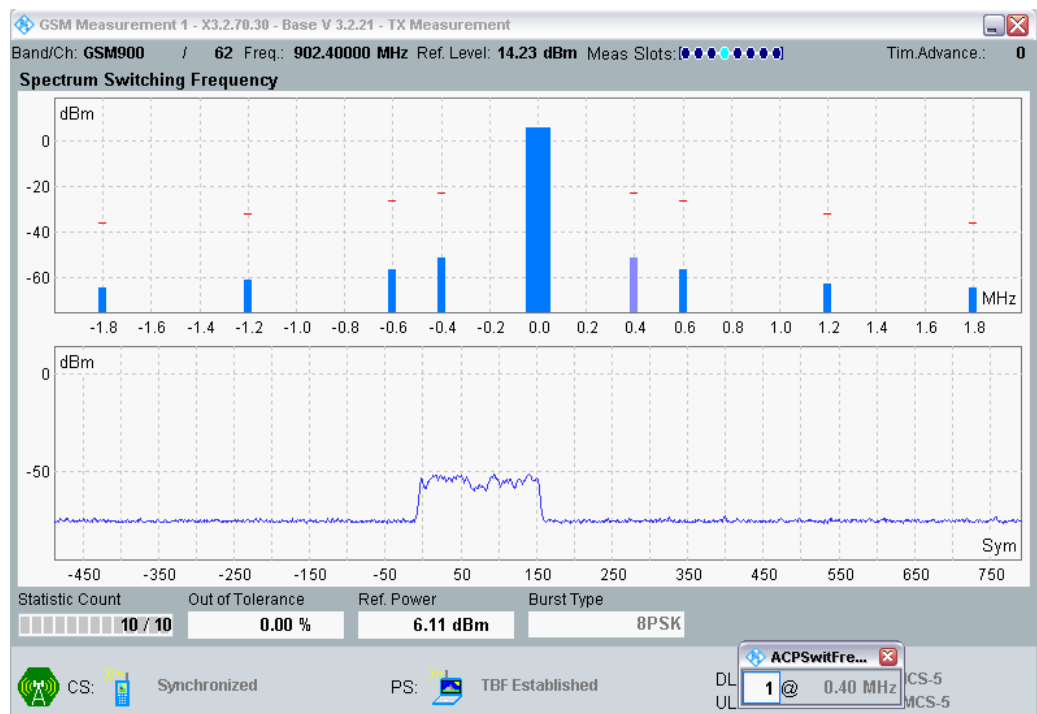

Fig. 10-13: PS power versus time @ 0.4 MHz offset, bandwidth 30 kHz.
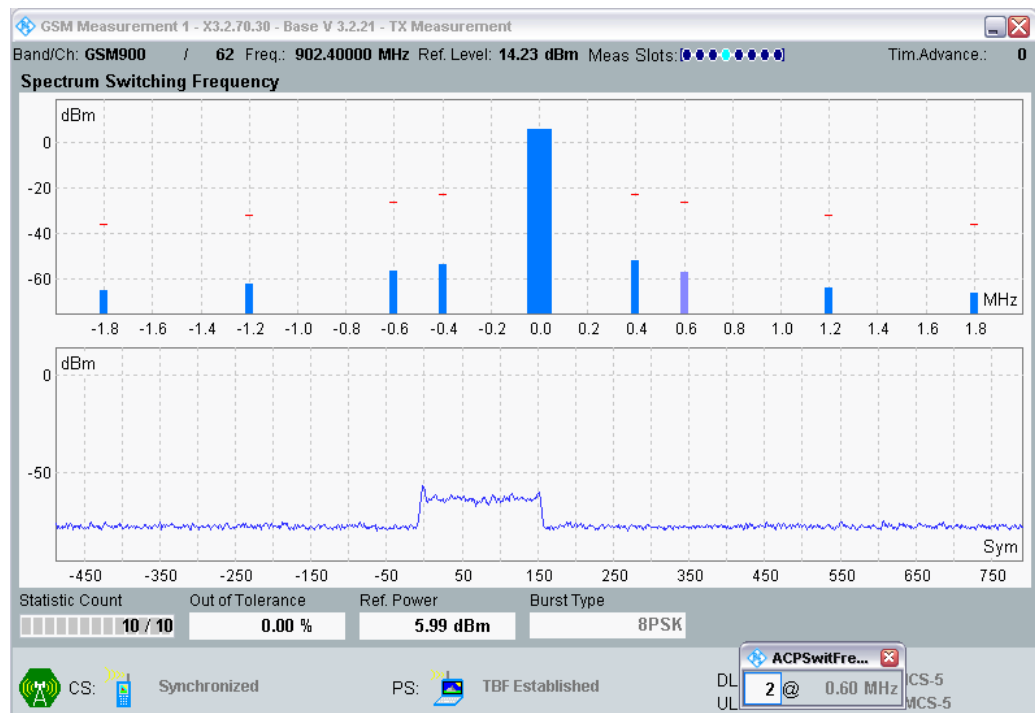
Fig. 10-14: PS power versus time @ 0.6 MHz offset, bandwidth 30 kHz.

Is the same true for your DUT?

The figures are taken from measurements on an 8-PSK-modulated signal.

The timing will subsequently be checked using a GMSK-modulated signal.

Is a different response to be expected for GMSK?

► End the PS connection.

► Perform the same measurement, but for CS (level also at 5 dBm).

shows the CS timing for the mobile phone used for this application note (at an offset of 400 kHz). The effect of the modulation is not as obvious here, but it is still present.
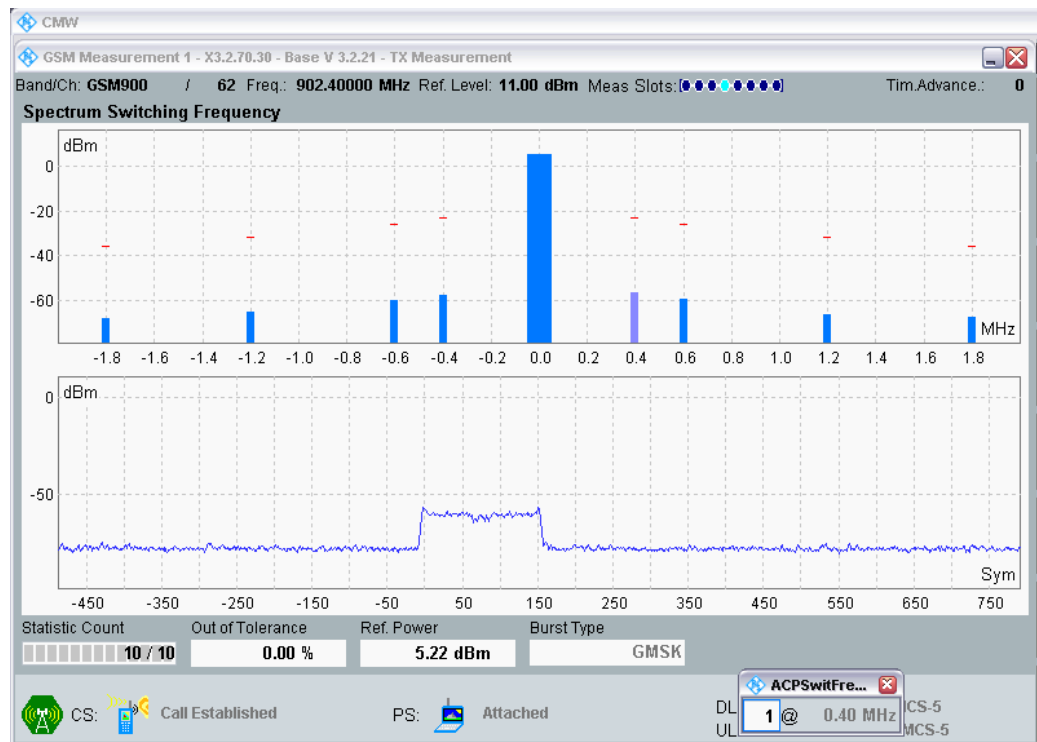
Fig. 10-15: **CS power versus time @ 0.4 MHz offset, bandwidth 30 kHz.**

Is the same true for your measurement results?

When looking at Fig. 10-15, it doesn't seem reasonable to acquire even during the modulated part of the burst for spectrum DTS – as required by the standard.

A measurement on a different, older mobile phone throws a different light on the spectrum measurements, however. See Fig. 10-16 on page 106.

Two things become obvious:

◗ The rising edge component now considerably outweighs the contributions from the modulation (and from the falling edge).

◗ The components for offsets 1 and 2 (400 kHz, 600 kHz) are almost 20 dB higher.
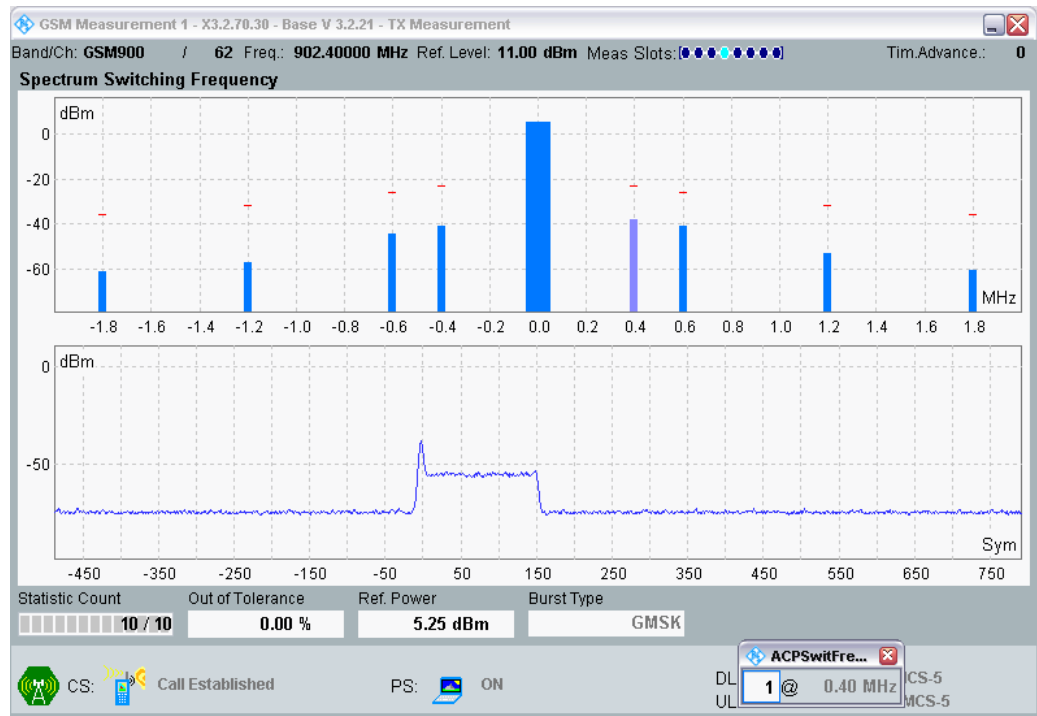
Fig. 10-16: Different DUT: CS power versus time @ 0.4 MHz offset, bandwidth 30 kHz.

This indicates that the modern DUT used for this application note has a DTS spectrum as low as "normally" the spectrum DTM. This is a pleasant surprise.

Summarize the results of spectrum measurements in your own words (differences between DTM / DTS, measurement methods, spectrum symmetry, effect of power, etc.).

11 GSM Measurements: RX Sensitivity

RX measurements measure the RF sensitivity of the receiver. In digital wireless communications, this is measured indirectly. At a low downlink level (the reference sensitivity level) defined in the specifications, the transmission errors must not exceed a defined percentage.

The goal is to learn the characteristic progression of bit and block error measurements before and after an error correction, as well as to take measurement readings and compare circuit-switched and packet-switched connections.

How is the sensitivity defined for analog transceivers?

Circuit-switched and packet-switched contents differ in two ways for GSM.

Circuit-switched (voice) connections use bit classes with different levels of error protection depending on their definition. These are measured based on these classes:

▪ Class Ia bits: Very good protection

▪ Class Ib bits: Low protection

▪ Class II bits: No protection

On packet-switched connections, all data is equally protected.

Circuit-switched connections always use GMSK modulation. Packet-switched connections can use GMSK, 8-PSK and sometimes also 16-QAM and 32-QAM modulation.

11.1 RX Sensitivity / Circuit Switched

Circuit-switched connections will be measured first:

▪ Burst by burst (bit error rate without error correction)

▪ BER (bit error rate with error correction)

▪ RBER/FER (residual bit error rate / frame erasure rate)

In all three cases, signaling is used to close a loop in the DUT that returns the received downlink signal back to the tester via the uplink, see Fig. 11-1 on page 108. An evaluation is then performed in the tester. A sufficiently high transmit level on the DUT ensures that no transmission errors are added to in the "return channel".

Loop C returns all received data burst by burst "sight unseen". The CMW calculates the bit error rate, i.e. the ratio of faulty bits to the total number of transmitted bits. (This is possible because the CMW knows what data was transmitted.) Thus, the analog stages and the demodulator of the DUT are tested.

The other loops include the decoder (with its error correction). While loop C primarily tests the analog components on the receiver, loops A through I cover the actual

application range of the mobile phone. Loops A, B and I differ only in which data is returned to the tester for evaluation.
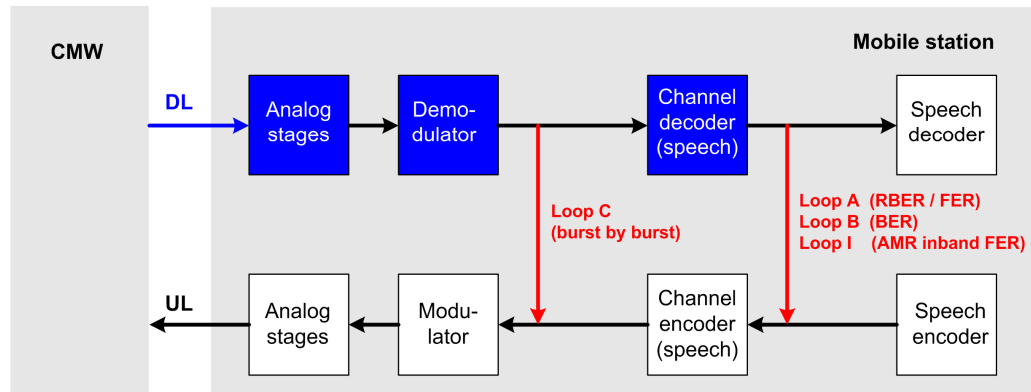

Fig. 11-1: RX loops for circuit switched.

Like loop C, loop B (for determining the bit error rate, BER) also returns the decoded bits from each class, but only after an error correction in the decoder. The CMW calculates the ratio of the faulty bits to the total number of transmitted bits.

Loop A marks frames in which the decoder could not correct faulty Class Ia bits as erased frames and returns zeros. The CMW then determines the ratio of these frames to the total number of frames as the frame erasure rate (FER).

For determining the bit error, loop A uses only frames that meet a minimum level of quality. This can actually lead to a temporary improvement in the BER for bit classes Ib and II when the downlink level drops because the frames, which become increasingly faulty, are marked as erased frames and are therefore no longer included in the calculation.

Bit errors in the frames remaining after the erased frames have been removed are displayed in the residual bit error rate (RBER) for loop A.

Measurement range

In line with standard TS 151 010, the test only requires that a specific error rate will not be exceeded for the reference sensitivity level. The reference sensitivity level for GSM900 mobile phones is defined at –104 dBm (CS).

These exercises additionally measure the error rates starting at –95 dBm using incrementally decreased input levels, until the level of the input signal is so low that the connection is lost.

Note: The tester and the mobile station both have a timeout counter that is started when SACCHs can no longer be decoded. Until the respective counter expires, the signal strength is continuously monitored to determine whether it returns to a satisfactory level. If it does, the connection is maintained; otherwise the connection is cleared down. These timeout counters were defined in the configuration window of the signaling task.

Preparation

The DUT should still be switched off.

► *RESET* the CMW and load the instrument configuration *LabConfig.dfl*.

► Open the GSM signaling main view.

► Switch the GSM signaling task on.

Once the connection status for *Circuit Switched* and for *Packet Switched* has changed to *ON*:

► Switch on the DUT and wait until the *Circuit Switched* or the *Packet Switched* status has changed to *Synchronized* or *Attached*.
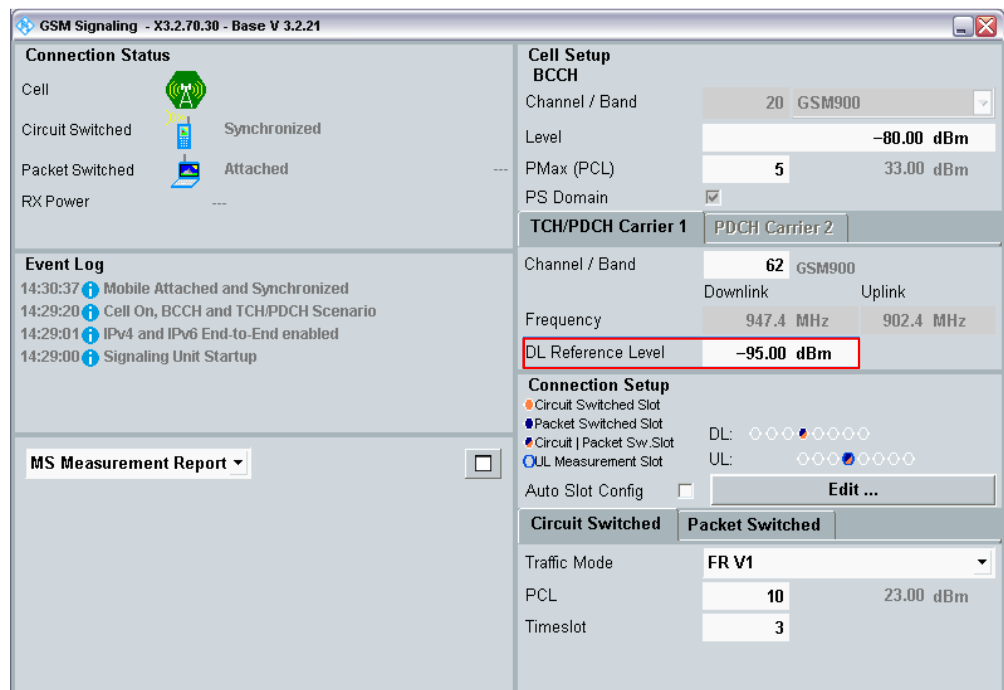

Fig. 11-2: GSM signaling main view / initial level for RX measurements.

► Set the *DL Reference Level* to –95 dBm.

► Press the softkey CS Connect.

► When the DUT "rings", open the shielded chamber and "pick up".

►   Close the shielded chamber.

►   Check whether the connection status changed to *Call Established*.

Start the BER measurement

►   Open the *GSM RX Meas* window. (The measurement task is still *OFF*.)
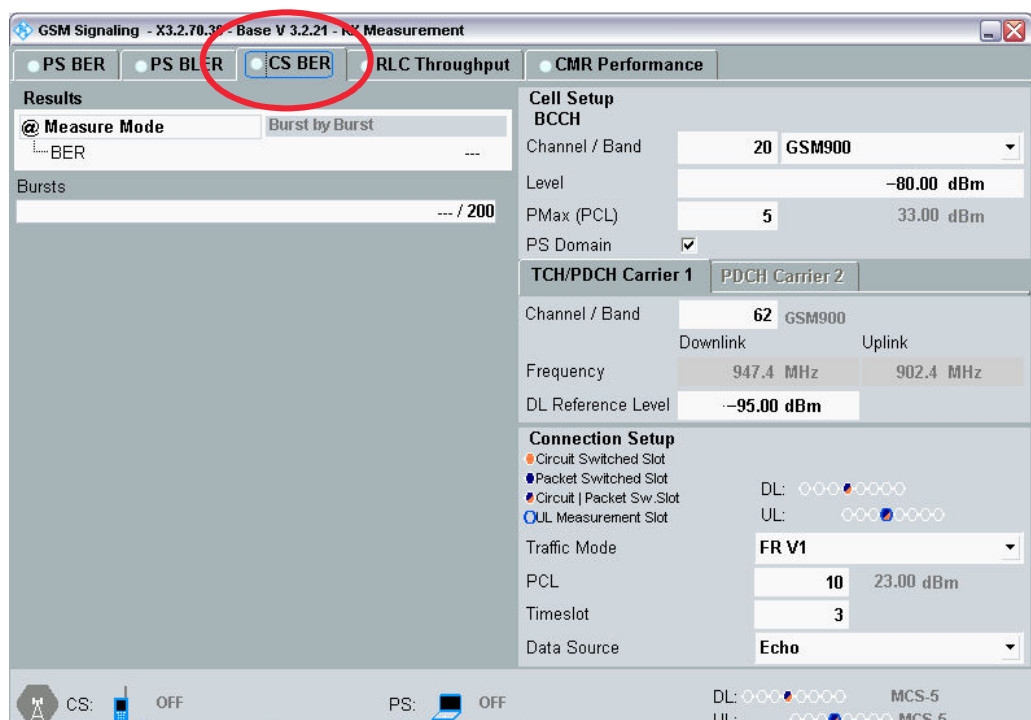
►   Select the *CS BER* tab.

Fig. 11-3: CS BER main view.

In order to ensure statistically reliable results, very large data volumes are defined in the GSM standard for sensitivity measurements, and the tests can last hours. To shorten this time, this application note is restricted to 200 frames being measured. The resulting speed advantage goes hand in hand with lower measurement accuracy. This is an accepted risk. What matters here are not the absolute numbers, but rather the opportunity to see the progression and recognize principle differences.

►   Check the settings:

Stop Condition (softkey) None.

Number of Speech Frames (softkey) 200.

Measure Mode (softkey) Burst by Burst. This corresponds to loop C, see .

Loop C, BER, Burst by Burst

► Press hardkey *ON/OFF* to start the measurement task.

Once the measurement of the defined 200 bursts is ended, the status display in the softkey *BER Circuit Switched* will show RDY. Press the hardkey *RESTART / STOP* (or press *ON* two times) to restart the measurement.

► Set up a series of measurements, each with an input level (*DL Reference Level*) that is decreased by 1 dB until the connection is lost.

► Make a note of your results.

When the connection is lost, the CMW reports "Radio Link Timeout". The connection status still shows "synchronized". If this happens:

► Switch the DUT off.

► Increase the DL reference level.

► Switch the signaling *OFF* and then back *ON*.

Once the connection status for *Circuit Switched* and for *Packet Switched* has switched to *ON*:

► Switch on the DUT and wait until the *Circuit Switched* or the *Packet Switched* status has changed to *Synchronized* or *Attached*.

► Set up the connection again by pressing *.. Connect*.

► Go to the next measurement series.

Loop B, BER

► Set the *DL Reference Level* to –95 dBm.

► Set the Measure Mode (softkey) to BER. This corresponds to loop B, see Fig. 11-1 on page 109. This setting deviates from the setup *LabConfig*!

► Set up a series of measurements, each with an input level (*DL Reference Level*) that is decreased by 1 dB until the connection is lost.

► Make a note of the results (Class II, Class Ib, CRC Errors).

Loop A, RBER, FER

► Set the *DL Reference Level* to –95 dBm.

► Set the Measure Mode (softkey) to RBER, FER. This corresponds to loop A, see Fig. 11-1 on page 109. This setting deviates from the saved setup!

► Set up a series of measurements, each with an input level (*DL Reference Level*) that is decreased by 1 dB until the connection is lost.

► Make a note of the results (Class II, Class Ib, FER, CRC Errors).

► End the CS connection.

► Display the measurement results graphically.

(The measurement results are not very accurate because of the low number of bursts. What matters here are not the absolute numbers, but rather recognizing the trend.)

Fig. 11-4 shows the BER traces for the mobile phone used for this application note.
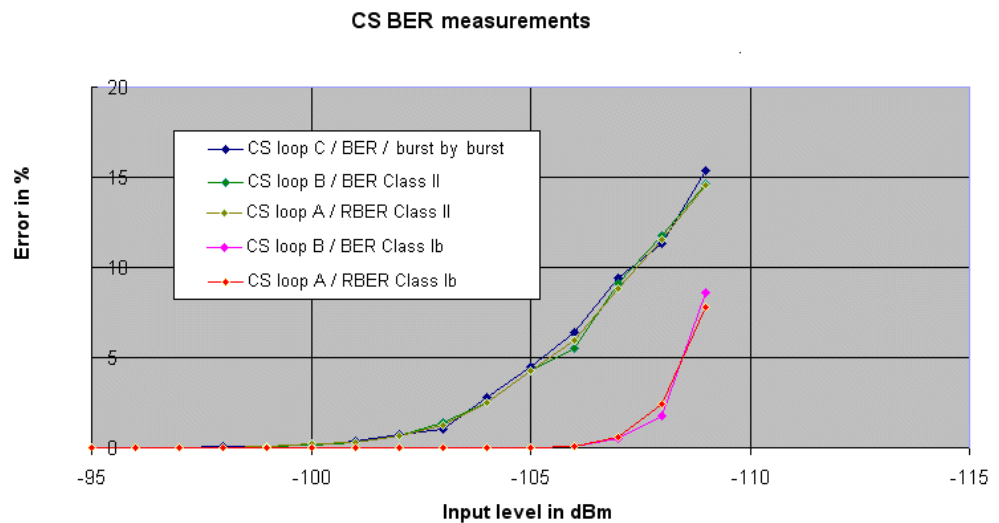

Fig. 11-4: CS total bit error display.

Are your measurement results comparable?

What can be said about the individual traces?

What do you see when you compare the results of loop C and loop B / Class II?

Why is this?

What do you see when you compare the results of loop B and loop A?

Why is this?

From the figure, it is evident that the bit error rate in unprotected Class II bits after the decoder is not any different than the error rate before the decoder. The error correction in the decoder for Class Ib bits can firstly completely eliminate a certain number of errors. With decreasing input level and an increasing number of errors, fewer and fewer percentage can be corrected this way, however.

11.2 RX Sensitivity / Packet Switched

This section describes two packet-switched measurements:

▪ PS BER, DBLER (bit error rate, data block error rate without error correction) and

▪ PS BLER (block error rate with error correction)

Packet data is typically organized into radio blocks (not just for calculating the bit or block error rate). Each of these radio blocks contains the data from four slots. This means that four frames are needed to transmit one radio block, which is equivalent to about 18.5 ms.

To keep the measurement times short, the measurements here will be limited to 200 radio blocks. The resulting measurement uncertainty is an accepted risk.

Measurements without error correction / PS SRB loop / BER, DBLER

In this case, the tester sets up an *SRB* loop in the mobile phone. *SRB* stands for "switched radio block" and means that blocks with packet data are transmitted. Like with loop C in the circuit-switched measurements, the *SRB* loop returns each received radio block to the tester, burst by burst and without error correction, see Fig. 11-5.
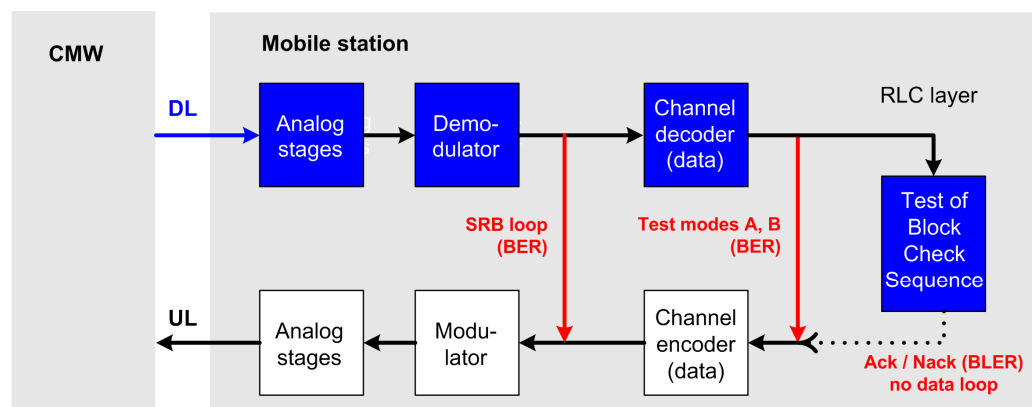

Fig. 11-5: RX loops for packet switched.

Normally, a radio block consists of a header, a data segment and a checksum (block check sequence BCS). For the *SRB* loop, the CMW transmits radio blocks without this checksum. Known pseudo-random sequences are used for the data. This makes it

possible for the CMW to detect every <u>bit</u> error. A <u>block</u> error is present if at least one bit error occurred.

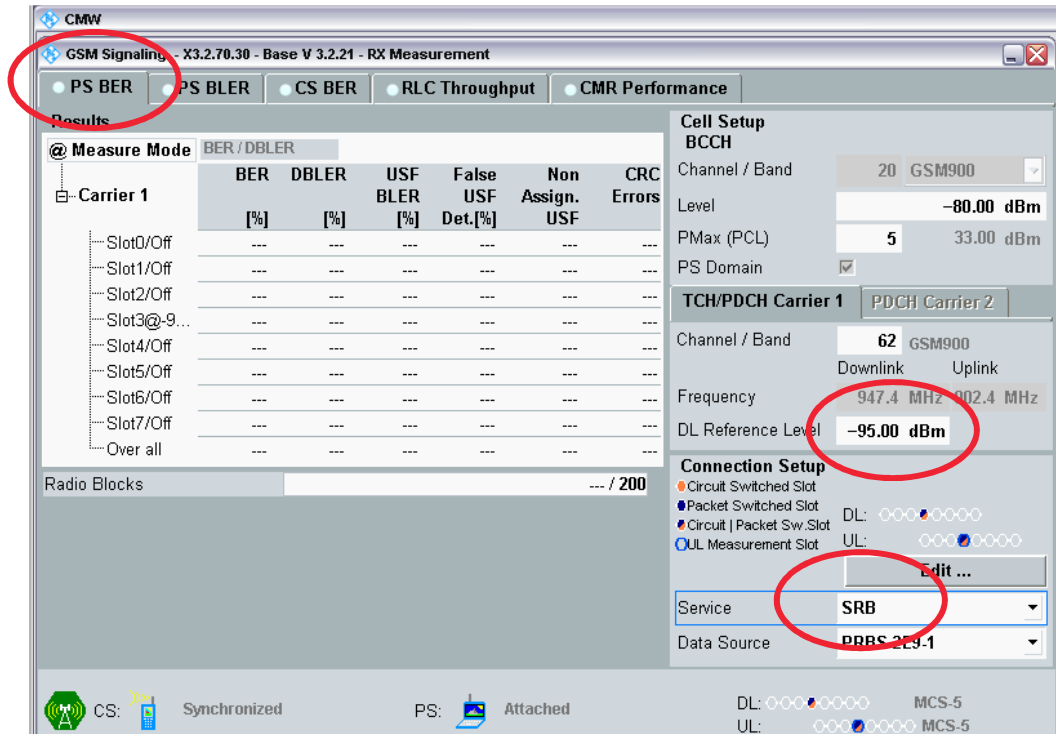► Open the *GSM RX Meas* window. (The measurement task is still *OFF*.)

Fig. 11-6: PS BER main view.

► Select the measurement *PS BER* (left tab), see Fig. 11-6.

► Set the *DL Reference Level* to −95 dBm.

► If another service is selected, change the selection to *SRB*.

► Verify the following settings and make any corrections necessary in the horizontal softkey bar:

   Stop Condition (None)

   Radio Blocks (200)

   Measure Mode (BER / DBLER)

How long do you think the measurement will take?

Measurement

► Set up a PS connection.

► Press hardkey *ON/OFF* to start the measurement task.

► Set up a series of measurements, each with a downlink level (*DL Reference Level*) that is decreased by 1 dB until the connection is lost.

► Display the measurement results for BER and DBLER graphically.

► End the PS connection.

The BER traces for the mobile phone used for this application note are located in Fig. 11-9 on page 117 together with the results from the RLC layer.

How would you interpret the traces you recorded?

Why is the block error rate (DBLER) so much higher than the bit error rate?

What can you say about the comparison of the results from PS BER (SRB loop) and CS BER (loop C)?

Why is this?

Why are there no CRC errors?

Why can't the next measurement (BLER loop) be started immediately, without breaking the connection?

Measurements with error correction / PS BLER

The next step is to determine the block error rate, which is defined by the RLC layer[18] after error correction by the channel decoder. (The bit error rates in test modes A and B are not considered here.)

In this case, the CMW uses radio blocks consisting of a header, a data body and a checksum (block check sequence BCS). A block is considered to be faulty if the checksum calculated in the mobile phone for the received block does not match the block check sequence in the block. The BCS is derived from the header and data segment of the current radio block. In contrast to DBLER measurement, transmission errors in the header will cause the radio block to be rejected.

There is no data loop. The mobile station performs the evaluation itself and sends an Ack / Nack message back to the tester, see Fig. 11-7 on page 116.

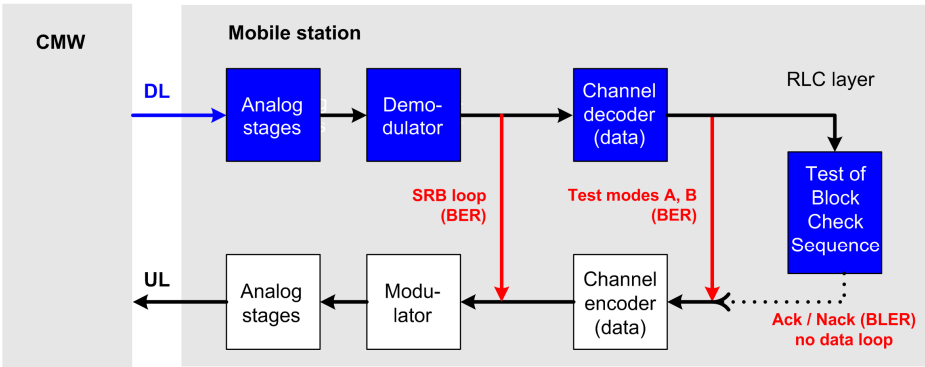[18] Radio link controller layer, which deals with the decoded and error-corrected radio blocks.

Fig. 11-7: RX loops for packet switched.

► Open the *GSM RX Meas* window. (The measurement task is still *OFF*.)

► Select the *PS BLER* measurement, see Fig. 11-8.

► Set the *DL Reference Level* to –95 dBm.

► Set the service to *BLER*.

This setting deviates from the instrument setup *LabConfig*!

► Verify the settings for the RLC data block count (200) and make any corrections necessary in the horizontal softkey bar.
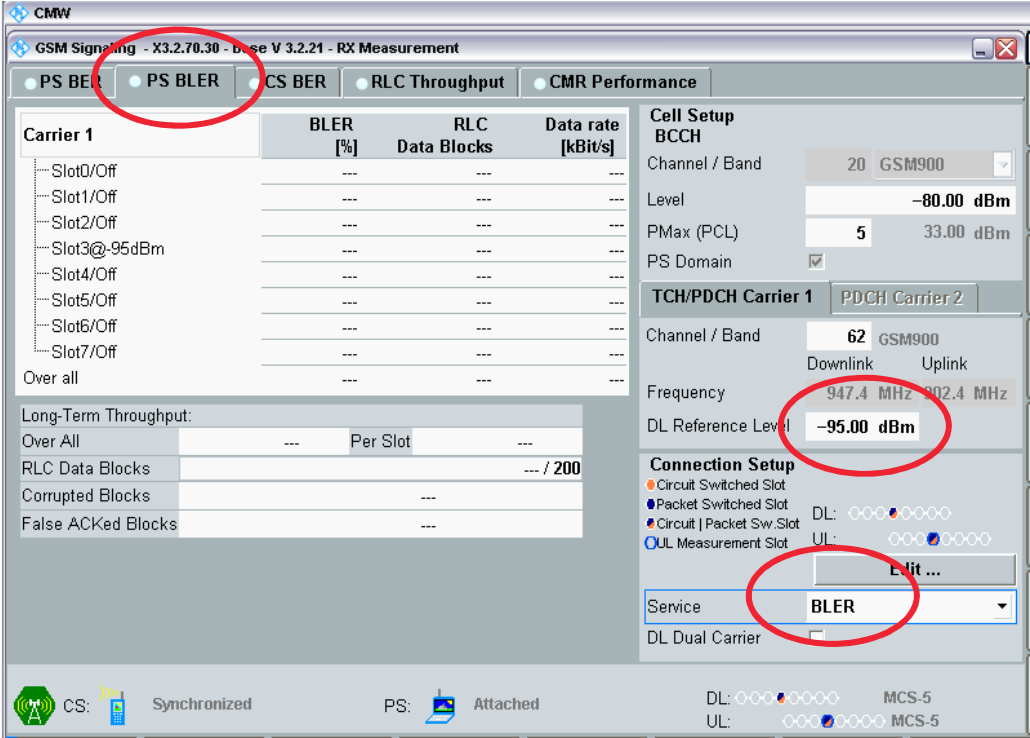

Fig. 11-8: PS BLER main view.

How long do you think the measurement will take this time?

Measurement

► Set up a PS connection.

► Press hardkey *ON/OFF* to start the measurement task.

► Set up a series of measurements, each with a downlink level (*DL Reference Level*) that is decreased by 1 dB until the connection is lost.

► Display the measurement results graphically.

► End the PS connection.

Fig. 11-9 shows a typical display together with the traces from the previous measurement.
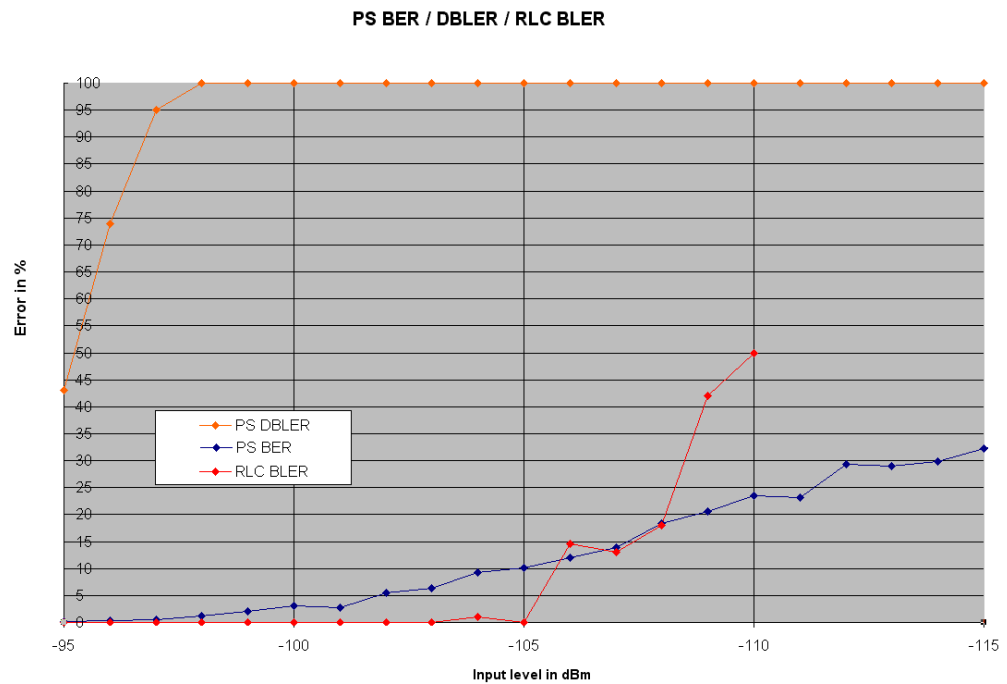

Fig. 11-9: PS total bit error display.

Are your measurement results comparable?

What can be said in general about the slope of the individual traces?

What can be seen when comparing the results of the CS BER in Fig. 11-4 on page 112 against the results of the PS BER and DBLER in Fig. 11-9?

Why is this?

Summarize the results of your RX measurements in your own words.

12 References

[1]   Analoge und digitale Modulationsverfahren (Analog and Digital Modulation Methods), Rudolf Mäusl / Jürgen Göbel, Hüthig‑Verlag Heidelberg, 2002

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[3]   Digital cellular telecommunications system (Phase 2+); Mobile Station (MS) conformance specification; Part 1: Conformance specification, 3GPP TS 51.010-1 version 10.3.0 Release 10, 2013

[4]   The GSM System for Mobile Communications, Michel Mouly / Marie-Bernadette Pautet, Cell & Sys Correspondence, Palaiseau / France, 1992

[5]   GSM-Signalisierung (GSM Signaling), Gunnar Heine, Franzis-Verlag München, 1998

[6]   R&S®CMW500 Wideband Radio Communication Tester, User Manual, Rohde&Schwarz®, 2013

[7]   R&S®CMW-KG2xx/-KM2xx/-KS2xx, GSM Firmware Applications, User Manual, Rohde&Schwarz®, 2013

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