Agilent

Optimizing Your GSM Network Today and Tomorrow

Using Drive Testing to Estimate Downlink Speech Quality

Application Note 1325

Introduction

This application note is a guide to understanding the air interface quality parameters of GSM (global system for mobile communications) networks and their relationship to downlink speech quality. These parameters are first defined and then the impact of network settings on their values is examined. Finally, the note shows which parameters and methods are best for estimating the speech quality of a GSM network under different operation conditions. Tools and methods for estimating uplink speech quality are not covered in this note. Also not covered are the basics of GSM technology; for information on this topic please refer to *Application Note 1344, Using Drive Testing to Troubleshoot Coverage, Interference, Handover Margin, and Neighbor Lists (literature number, 5980-0218E).*

The measurements described in this note are made using phone-based drive test tools that measure air interface parameters (figure 1) instead of specialized MOS scoring systems. (Refer to the 'Product Literature' section at the end of this document for more information on automated uplink and downlink voice quality MOS-scoring solutions from Agilent.)

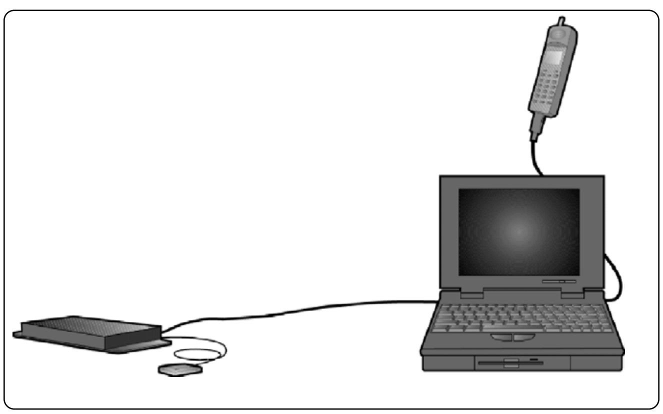

Figure 1. Phone-based drive-test system with GPS receiver and antenna.

Air interface quality parameters

RXQUAL

RXQUAL (received signal quality) is a BER (bit error rate) measurement done by the mobile on the midamble of the burst (see figure 2). This measurement is done over all the received frames within a measurement period of 480 ms and reported back on the SACCH (slow associated control channel). The RXQUAL measurement is done over 104 TDMA (time division multiple access) frames, but the measurement in the 4 idle frames is optional, hence in practice the measurement will be averaged over 100 TDMA frames. The reported value is the average of the BER received over all the frames and rated in one of the eight RXQUAL bands (0 through 7); 0 is the lowest BER i.e. best performance and 7 is the worst case.

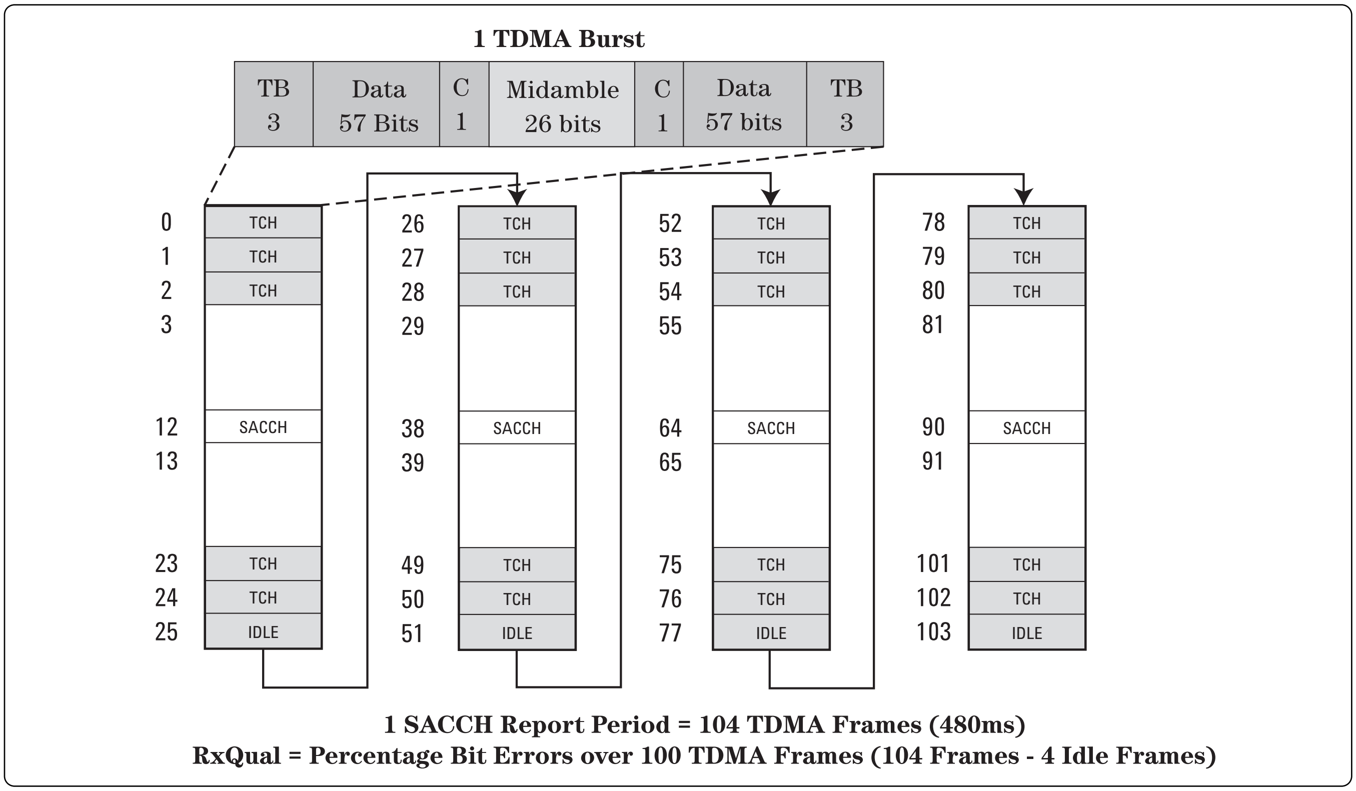

Figure 2. TDMA burst, frame and RXQUAL

RXQUAL has two variants; RXQUAL_FULL and RXQUAL_SUB. FULL and SUB refer to the measurement frames (figure 2). When the measurement is performed over all the frames received, then it is FULL. If even one frame

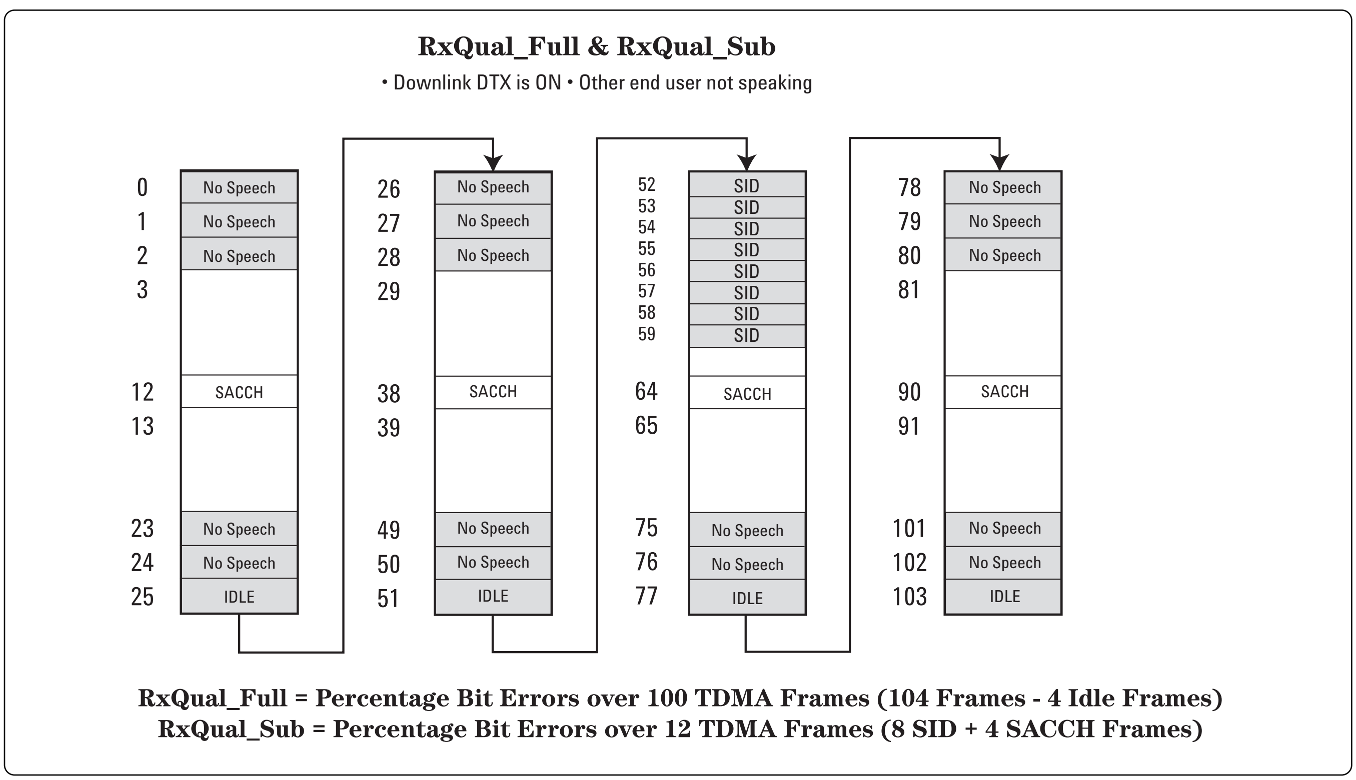

Figure 3. RXQUAL_FULL and RXQUAL_SUB

(out of 104 frames) is not included in the measurement averaging process, then the measurement is SUB. The mobile will report both SUB and FULL values in the SACCH report.

When do we consider RXQUAL_SUB measurements?

Before describing the situations in which SUB measurements are considered, this note will explain DTX (discontinuous transmission) and SID (silence descriptor) frames.

DTX is an air interface process by which the active radio transmission is cut off when there is no speech activity. Inside the base station transcoder and mobile phone there is a DTX handler. The DTX handler has a VAD (voice activity detector), which detects the presence and absence of speech in the presence of stationary background noise. To prevent annoyance to the listener when transmission is cut off, the DTX handler also generates samples of stationary background noise (known as comfort noise) and transmits them at regular intervals (once every 480 ms) to the other end during periods of speech inactivity. The receiver will generate continuous background noise using these samples.

The mobile and the base station detect the activity of DTX on the air interface with the help of SID frames. These SID frames (each is 20 ms in duration and contains 260 bits) have a unique pattern consisting of 95 bits of zeroes, which identifies them as speech. The receiver (base station or mobile) can use the comfort noise samples inside the SID frames to generate continuous noise.

If downlink DTX is enabled at the base station and active during the measurement period, then the FULL and SUB measurements will differ. FULL will report a poor value compared to SUB. In most cases, when DTX is on during the 480 ms measurement period, there will be no speech and hence the SUB measurement will be done over only 12 frames (4 SACCH + 8 SID). However, the FULL measurement will be done over all 100 frames (104 - 4 idle), out of which 88 frames will contain nothing if there is no voice activity; hence, the FULL measurement will report a poor RXQUAL in the range of 6 to 7. This is illustrated in figure 3 for one SACCH reporting period. It is useful to note that a delta measurement on the FULL and SUB measurements indicates the voice activity.

In a GSM cell, a BCH (broadcast channel) carrier has to be in a continuous on state (i.e., continuous transmission at a constant power level in all the timeslots). Therefore, if the call is on a BCH carrier, DTX cannot be used in the downlink, and the mobile will report the same value for RXQUAL_FULL and RXQUAL_SUB. Therefore, neither FULL nor SUB measurements are useful for measuring speech quality on a BCH carrier. In this situation, FER (frame erasure rate) can provide a better way to estimate speech quality.

FER (Frame Erasure Rate)

GSM codes speech in 20-ms frames. In each frame, a 3-bit CRC (cyclic redundancy code) is added to the 50 most significant bits (see figure 2). When the mobile decodes the 260 bits received in the frame, it verifies the 3-bit CRC for the 50 most significant bits. If the CRC check fails, the frame is erased and not passed to the vocoder for speech decoding. Since only 3 bits are used for the CRC, the probability of detecting bad frames is very low. This probability increases with the use of an EFR (enhanced full rate) coder, which uses 8 bits in the preliminary coding stage and 3 bits in the next stage, similar to the FR (full rate) coder.

FER is not measured routinely in GSM operations. The FER measurement is used by the mobile to detect bad frames. Once bad frames are detected, the mobile starts the substitution and muting process, and within 300 ms of bad frame reception it completely mutes the speech.

A test mobile can report the FER as the percentage of the total frames received that are erased. Some test mobiles allow adjustment of the "number of frames for measurement." Typically, FER measurements should be done over 100 frames, which corresponds to 2 s of speech. Speech is usually intelligible over this duration.

In GSM, since quality control operations are related to SACCH frame periods of 480 ms, the test mobiles typically have a period of 4 measurement cycles, which corresponds to 19.2 s or 96 (24 x 4) speech frames.

If the FER is above 2 to 3 % for a period of 3 to 5 s, the user will start experiencing a "Ping-Pong" sound similar to that of a breaking bottle.

The FER measurement is done after Viterbi decoding and over actual speech bits. Thus, if DTX is active, the 260 bits will include 95 fixed zero bits, which the decoder will detect as a SID frame and not a speech frame. (Further explanation of SID frames is provided below in the section "Downlink discontinuous transmission on".)

Under active DTX conditions, the number of frames for FER measurements will be reduced to as low as 8 SID frames (refer to figure 3). In this case, the FER value will be high if even 1 frame is bad.

RLT (radio link counter)

The RLT (radio link counter) is not a parameter that is measured over speech frames; it is set to a value decided by the network operator. This value is in units of SACCH frames (see figure 1). If the mobile is not able to decode a SACCH frame, then this counter decrements by 1. If the decoding is successful, then it is incremented by 2, but it will not exceed the set value. Since the SACCH frame has 40 bits used for the CRC, the probability of detecting bad frames accurately is high. Hence, a decrement in the RLT value indicates a serious situation. When this counter reaches 0, the mobile will declare radio link failure, consider the call as dropped and return to the idle state (see figure 4).

We can use the RLT in conjunction with the actual measured and reported speech quality parameters to arrive at a precise estimation of speech quality.

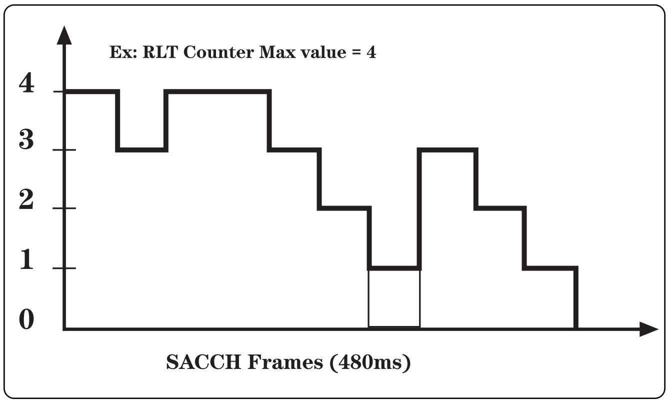

Figure 4. Radio link counter

What parameters should be used to estimate downlink speech quality?

This section of the application note explains which parameters are best for estimating speech quality under various network conditions.

No DTX or frequency hopping

We can comfortably rely on RXQUAL in this situation. An RXQUAL greater than 4 for a long period will result in clicks and minor deterioration in speech quality. If RXQUAL ranges between 6 and 7 for a significant period, FER will increase significantly; if FER exceeds 3% for 2 to 5 s, a considerable deterioration in speech quality will be noticed.

FER and RXQUAL will follow a linear relationship under these network conditions.

Frequency hopping on

With frequency hopping, RXQUAL becomes erratic and does not provide a true picture of speech quality. For example, if there are five frequencies used in the hopping list, each frequency might occur at least 20 times in one measurement cycle of 100 frames. If only two frequencies are experiencing problems, then 40 bursts will have a high RXQUAL (6 or 7) and the rest could all have an RXQUAL of 0 (see figure 5). However, when the mobile reports the RXQUAL in the measurement period, it is an average; hence, the reported RXQUAL will be less than 3. Bursts received on problematic frequencies can definitely result in a deterioration of speech quality, despite the effect of interleaving. Since we aren't provided with burst-by-burst BER measurements, we cannot rely on RXQUAL to estimate speech quality. Under these conditions, FER is a more precise method of estimating speech quality. If RXQUAL and FER are reported high for a long period, this indicates that the frequency hopping implemented is ineffective, and optimization of hopping parameters is required.

Downlink DTX on

With downlink DTX on, the number of frames over which the FER measurement is done will vary between 8 and 96. In most of the cases when DTX is active, the speech inactivity period will be more than 2 s; this means the number of frames will be 8, and hence FER values will be high, even with slight deterioration in quality. However, periods of voice inactivity are not the only times that DTX can be active. The VAD also detects stationary sound over a period of 480 ms and cuts off transmission by sending a sample of this stationary sound to the mobile for its internal generation of background sound. This is the actual information present in the SID frames that occur twice during the 480 ms cycle. figure 6 illustrates an example of DTX operation. When there is no speech, the base station

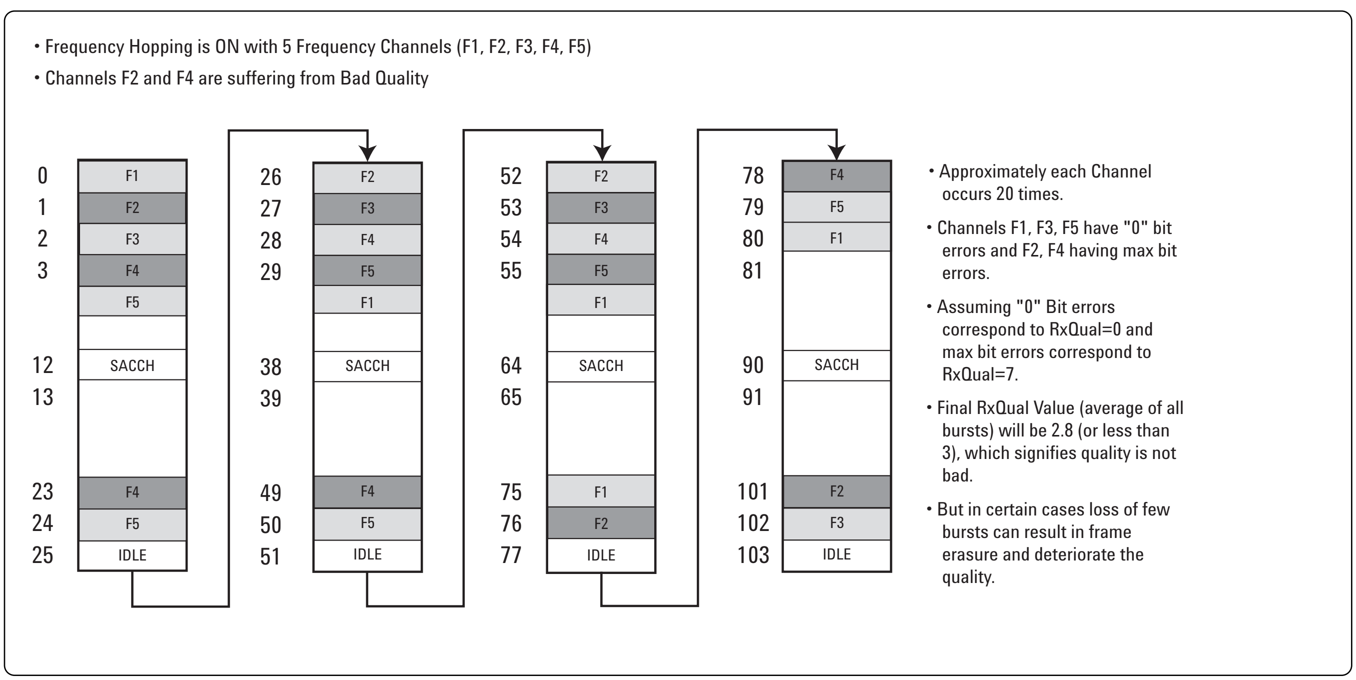

Figure 5. Effect of frequency hopping on RXQUAL

subsystem (BSS) will receive a SID indication from the phone on the left. The base station will in turn send a SID frame to the phone on the right. Every 480 ms the phone will update the background noise.

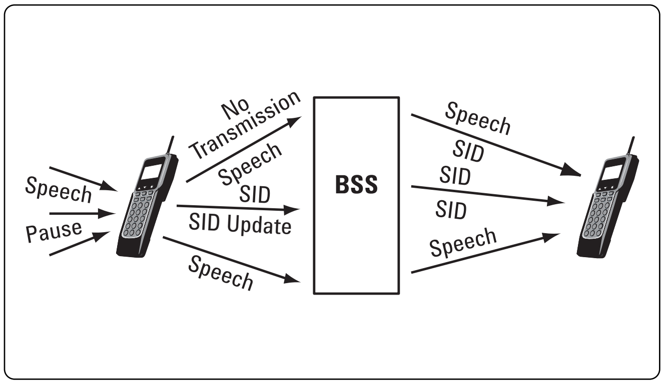

Figure 6. DTX operation

There are several types of voice signals that can be used to set up calls to estimate speech quality. If your called number has continuous-tone information, the FER measurements will be high. This continuous tone will be detected as background noise by the VAD, and thus only SID frames will be on; therefore, the FER will always start with values above 10%. However, the speech quality will not be poor unless there is continuous deterioration of air interface quality, which will be indicated by the Radio Link Counter.

It is therefore preferable to avoid tones for speech quality estimation by FER. There are other called numbers that should also be avoided; an example is the "Speaking Clock," which has long pauses in information followed by tones and beeps.

An ideal method is to call a music number that has continuous variations in sound, or another cell phone (or a PABX number), and keep your call on hold from the other end.

In all situations with DTX on, consider higher values of FER for benchmarking and correlate FER with RLT values. Typically, 2% FER is considered poor. With DTX on, the FER rating should generally be higher than 2%. However, this depends on the type of number called, so we can't simply specify a number for FER. Therefore, the value that we use for benchmarking FER under non-DTX conditions might not apply for DTX conditions.

Note: RXQUAL_SUB and FER will show a linear relationship with high values of FER. This means a high value of RXQUAL_SUB (for example, 6 or 7) will be linked to a high value of FER.

MOS (mean opinion score)

Another method of measuring speech quality is the MOS (Mean Opinion Score). There are five grades for MOS; grade 5 is excellent and grade 1 is poor. MOS measurements can be done by voice quality systems, which use voice scripts or similar techniques for sending a known voice pattern from a fixed central unit and analyzing it with a mobile receive unit. Automated MOS scoring is not covered in this application note. However, a manual approach to MOS scoring is included in the next section. (Refer to 'Product Literature' for more information on automated voice quality testing using the Agilent VoicePrint system and RECON services.)

The what and why approach

If we determine by any method that speech quality is poor, we will also want to know why. The most effective way to find the cause of poor quality is to measure the impairments along with the air interface quality parameters.

The major impairments on the air interface are coverage problems, co-channel interference, adjacent channel interference, multipath, and delayed or failed handovers. These impairments contribute to nearly all speech quality problems.

The Agilent E7475A GSM-based drive test system, which includes a test mobile phone and receiver, can measure both impairments and air interface parameters (see figure 7). The system collects all the relevant air interface parameters, and performs real-time co-channel and adjacent channel interference measurements. The ability of the system to collect all relevant air interface parameters (phone and receiver), and the receiver's ability to perform co-channel and adjacent channel interference, allow the user to determine the reasons for call quality problems without being concerned about which parameters apply under different network conditions.   The phone identifies the nature of the problem (for example, high RXQUAL), and the receiver shows why the problem is occurring (for example, co-channel interference).

The fast scanning receiver in the E7475A can determine the probability of the presence and absence of a signal. Refer to the BCH analyzer display in figure 8.

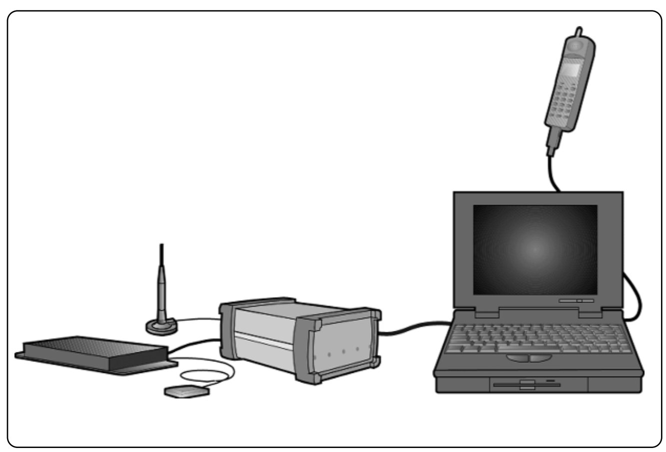

Figure 7. Integrated phone- and receiver-based drive-test system

Figure 9 illustrates how the integrated phone-and-receiver-based drive test solution can be used to measure manual MOS and C/I (carrier-to-interference ratio) simultaneously. The results are exported to MapInfo. The receiver automatically measures C/I for the co-channel interferer.

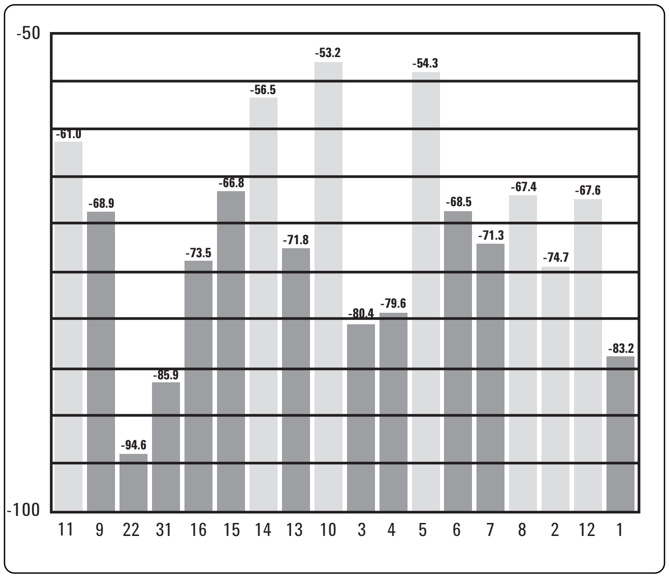

Figure 8. BCH analyzer display

When printed in color, the plot would show C/I values of 0 to 9 dB in red (poor performance) and values greater than 10 dB in green (better performance). Then, with the test mobile phone connected to a car kit, manual MOS measurements are performed by the user's subjective interpretation, and the results are exported to the map display. E is excellent, G is good, B is bad, and WORST is the worst speech quality. These results are stored in the database as the user presses the corresponding key on the laptop PC. Areas of bad and "worst" quality correspond to locations where the receiver measured C/I of less than 9 dB. In summary, an integrated drive test solution can determine what the problem is, and it can also indicate why it happened; for example, poor speech quality caused by high levels of co-channel interference.

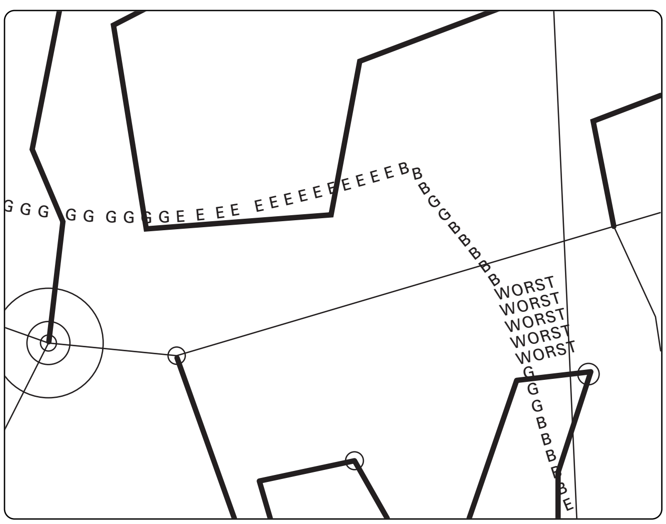

Figure 9. C/I and manual MOS measurements

Conclusion

We have examined the air interface quality parameters and their suitability for estimating speech quality with a phone-based drive test system under various network conditions. Under complex operating conditions created by features such as DTX, frequency hopping and downlink power control on, we need to adopt various methods for estimating speech quality. All these features tend to reduce average interference and thus provide an average improvement in speech quality. Occasional spikes in the values of these parameters do not usually indicate problems. An integrated phone-and-receiver-based drive test system can help identify a speech quality problem and its cause.

Acronyms

DTX	discontinous transmission
EFR	enhanced full rate
FER	frame erasure rate
FR	full rate
GSM	global system for mobile communications
MOS	mean opinion score
PABX	private automatic branch eXchange
RLT	radio link counter
RXQUAL	receive quality
RXQUAL_FULL	receive quality over full 104 TDMA frames
RXQUAL_SUB	receive quality over subset of 104 TDMA frames
SACCH	slow associated control channel
SID	silence descriptor
TDMA	time division multiple access
VAD	voice activity detector

Product literature

1. *GSM Drive-Test System Technical Specifications*, Agilent literature number 5968-5564E

2. *GSM Drive-Test System Configuration Guide*, Agilent literature number 5968-5563E

3. *GSM Drive-Test brochure*, Agilent literature number 5968-5562E

4. *Indoor Wireless Measurement System Product Overview*, Agilent literature number 5968-8691E

5. *GSM Application Note 1344: Using Drive-Testing to Troubleshoot Coverage, Interference, Handover Margin and Neighbor Lists*, Agilent literature number 5980-0218E

6. *Product Overview: Agilent Portable VoicePrint System*, Agilent Literature Number 5988-0248EN

7. *Product Overview: Agilent RECON Wireless Market Reports*, Agilent Literature Number 5988-0250EN

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