Voice Quality Enhancement Technology Improvements for AMR Codecs in GSM Networks

Executive Summary

The desire to increase voice quality and call capacity continues to drive the evolution of codecs within the Global System for Mobile Communications (GSM) environment. The introduction of the Adaptive Multi-Rate (AMR) codec is consistent with this evolution; however, operators can employ additional Voice Quality Enhancement (VQE) tools to further extend these benefits.

VQE technology that reduces noise impairment from voice calls increases the call capacity of a radio resource by retaining the low-bandwidth consumption associated with AMR Half-Rate (AMR HR) codecs as the Radio Frequency (RF) characteristics change. Additionally, the introduction of VQE technology can enable carriers to re-evaluate the Frame Erasure Rate (FER) settings associated with the selection criteria between AMR Full-Rate (AMR FR) and AMR HR codecs. Lastly, VQE technology can improve the overall Mean Opinion Score (MOS) for a majority of AMR calls.

This document introduces the concepts used to build the AMR codec and highlights some of the limitations in using the lower bit rate codec. We will also compare the performance of the AMR codec to preceding GSM codec types. Most importantly, this paper defines the benefits to AMR-coded speech quality through the removal of speech impairments like acoustic echo, excessive background noise and sub-optimal signal levels.

Advantages of Using the AMR Codec

The AMR codec was introduced by the 3GPP Forum for GSM and Universal Mobile Telecommunications System (UMTS) technologies. The key aspect of AMR speech codecs is that they offer a variety of speech rates that can be provided on a dynamic basis. When an AMR channel is chosen for a voice conversation, the AMR speech codec can be modified dynamically throughout the call based on current channel conditions.

Mulltiple speech codec rates and dynamic switching between them is useful to maintain the voice quality during bad RF and channel conditions. Together, the channel and speech coded bits use up the GSM channel capacity of 25.3 kbps. More bits are used for channel coding when channel conditions deteriorate, trading off bits used for speech coding. Thus, dynamic switching of speech codec rates makes it possible to maintain speech quality when using an AMR channel.

There are typically two kinds of channels available in a GSM network, the Full Rate (FR) channel and Half Rate (HR) channel. The HR channel uses one half of the capacity of the FR channel. The FR channel has a capacity of about 25.3 kbps (26 frames in 120 ms), the HR channel has one-half that capacity. AMR offers eight different codec rates for FR channel and six different rates for HR channel.

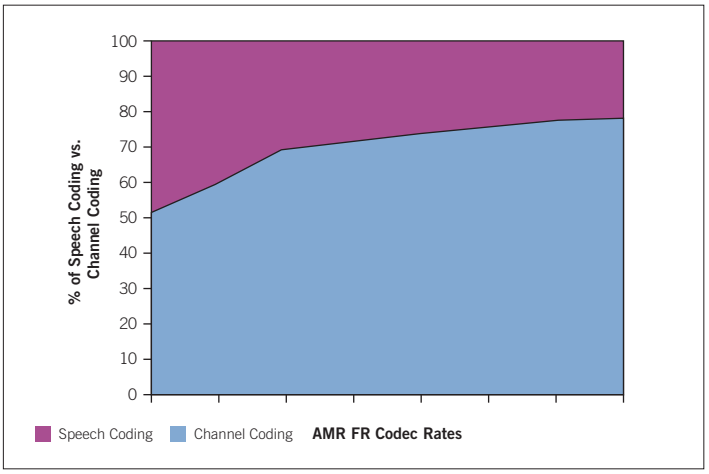


Figure 1. Comparison of channel coding and speech coding to various AMR FR speech rates.

When channel conditions are good, the HR channel can be used with AMR codecs. In this situation the call capacity doubles. However, when channel conditions worsen, speech codec rates are dynamically modified to accommodate channel conditions.

Figure 1 shows a comparison of the percentage spread for channel coding vs. speech coding for various AMR FR rates. Channel conditions determine the coding required to transport speech — when channel coding increases, speech bits decrease. During bad channel conditions additional channel coding bits are used to provide robust mechanisms and transport the speech bits to the receive end.

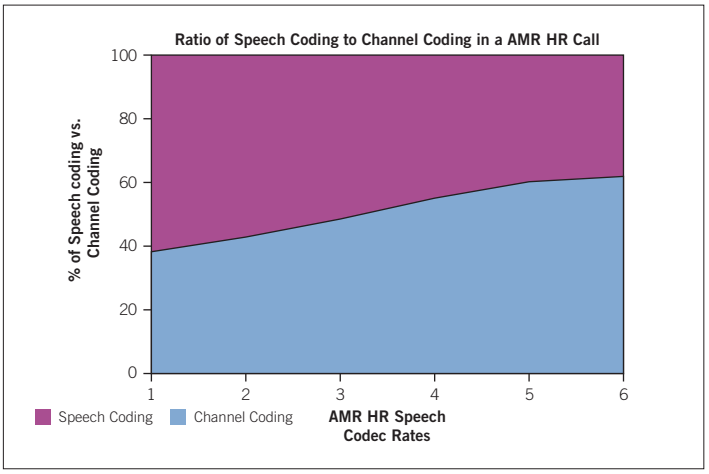
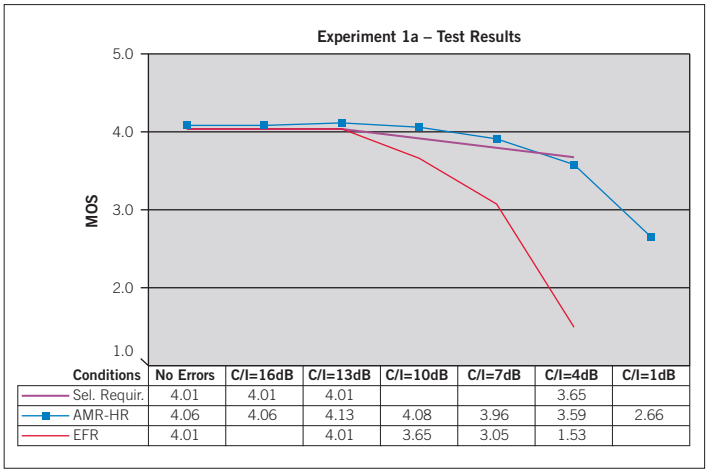


Figure 2. Comparison of channel coding and speech coding to various AMR HR speech rates.

Similarly, when channel conditions are good an AMR HR channel can be used for the voice call. However, if the mobile user moves away from the base station or channel conditions deteriorate, channel coding and speech coding rates are modified to support the channel conditions. When the predetermined threshold for AMR HR channel conditions are met the call switches to the AMR FR channel so the voice conversation can continue. Figure 2 compares speech coding to channel coding various AMR HR speech rates.

Speech Quality and AMR Codec Rates

By virtue of definition, AMR codecs can dynamically increase channel coding to accommodate bad channel conditions and sustain voice quality. The 3GPP Forum performed various tests and published its results in 3GPP TS 06.75. Figure 3 illustrates the performance of AMR FR speech compared to Enhanced Full Rate (EFR) during similar channel conditions. This comparison defines the impact to Mean Opinion Score (MOS) with various Carrier to Interference (C/I) levels.

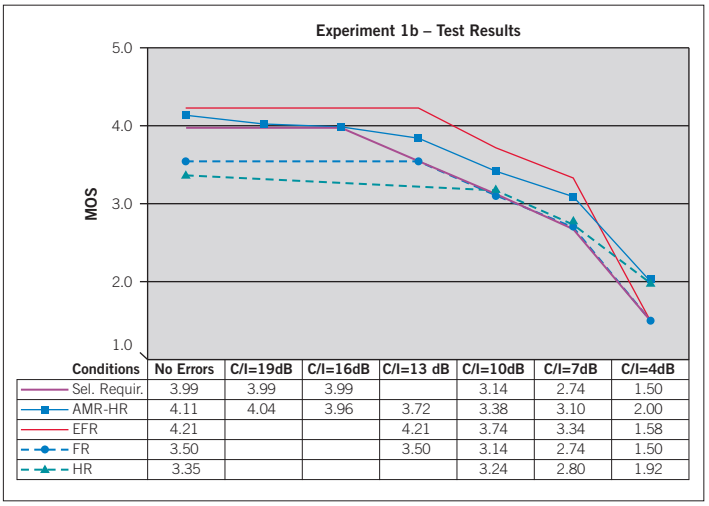


Conditions	No Errors	C/I=16dB	C/I=13dB	C/I=10dB	C/I=7dB	C/I=4dB	C/I=1dB
Sel. Requir.	4.01	4.01	4.01			3.65	
AMR-HR	4.06	4.06	4.13	4.08	3.96	3.59	2.66
EFR	4.01		4.01	3.65	3.05	1.53	

Figure 3. AMR full rate – clean speech performance curves.

During poor channel conditions, AMR increases the Forward Error Correction (FEC) part of channel coding to improve the robustness in transporting speech and to prevent additional Bit Error Rates (BER) or Frame Erasure Rates (FER). This means the speech coded bits are traded for the channel coding bits, as the total bandwidth available to transport bits is fixed at 25.3 kbps (ref 3GPP TS 05.02). The adaptive nature of the AMR FR codec enables significant improvement when compared to the EFR codec.

The 3GPP also introduced the AMR HR codec. Though the performance of the AMR HR codec is inferior compared to EFR, the AMR HR codec improves wireless infrastructure utilization by doubling the call capacity, i.e. supporting two calls on a single traffic channel. This performance study has also been published in 3GPP TS 06.75 and Figure 4 illustrates the performance comparison of AMR HR with EFR, FR and HR.



Conditions	No Errors	C/I=19dB	C/I=16dB	C/I=13 dB	C/I=10dB	C/I=7dB	C/I=4dB
Sel. Requir.	3.99	3.99	3.99		3.14	2.74	1.50
AMR-HR	4.11	4.04	3.96	3.72	3.38	3.10	2.00
EFR	4.21			4.21	3.74	3.34	1.58
FR	3.50			3.50	3.14	2.74	1.50
HR	3.35				3.24	2.80	1.92

Figure 4. AMR half rate – clean speech performance curves.

Although the AMR HR does not perform as well as EFR, it does outperform GSM FR and GSM HR in poor channel conditions. This is detailed in the field trial data shown in Figure 8. AMR HR is attractive to operators who wish to take advantage of capacity gains; however, voice quality performance considerations need to be made due to the performance differences between AMR FR and AMR HR.

Noisy Conditions and AMR Speech

The data indicates that the clean AMR FR speech performance is better than EFR, and that AMR HR has a reasonable performance in comparison to EFR. 3GPP tested the AMR speech in noisy conditions, publishing results for AMR performance in a 15dB SNR street noise environments, as illustrated in Figure 5 for AMR FR and Figure 6 for AMR HR. The overall behavior of AMR FR speech was similar to EFR speech with background noise, but AMR HR began to degrade in noisy environments.

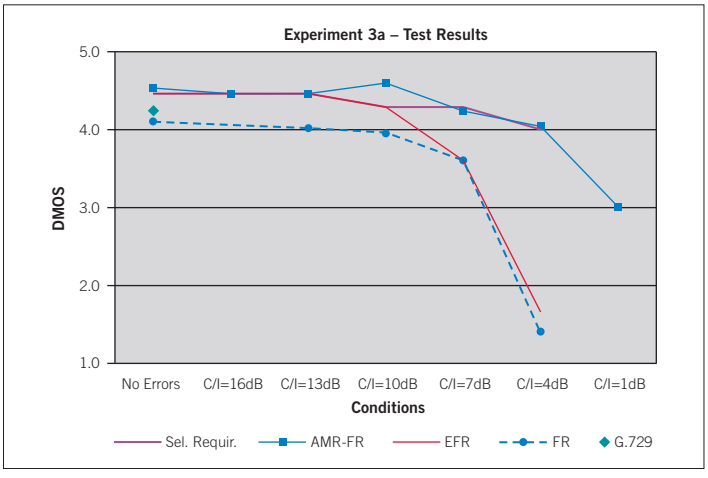


Figure 5. AMR FR performance curve with street noise.

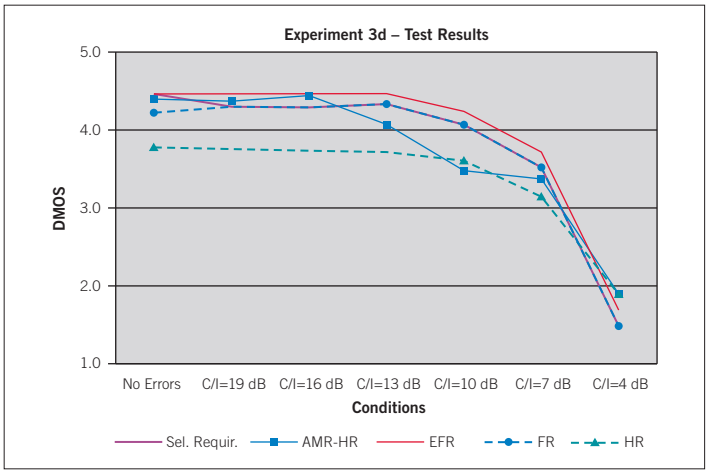


Figure 6: AMR HR performance curve with street noise.

The 3GPP Forum, as part of standardizing AMR codecs, identified this limitation and set performance guidelines for noise suppression in 3GPP TS 06.77 to ensure that handset manufacturers make provisions to remove background noise before speech is encoded. Also, operators may choose to limit the set of codecs deployed in their network, hence limiting the voice quality problems.

These guidelines are not mandatory and speech performance testing is subjective, resulting in voice quality issues still present in the network.

Tellabs Voice Quality Enhancement (VQE) Solutions

Tellabs offers a suite of voice quality enhancement solutions that include acoustic and hybrid echo controls, background noise reduction, adaptive gain control and level control. This comprehensive set of solutions can augment the deficiencies of the low bit rate AMR HR codec.

Tellabs Voice Quality Enhancement (VQE) is a network-based solution that caters to all the users independent of mobile handsets and speech coding mechanisms used in the network. The critical aspect of network-based VQE is that it offers a consistently improved user experience across the network. This solution is deployed on a standard A-interface of the GSM network at the Mobile Switching Center (MSC), as depicted in Figure 7.

Tellabs VQE solutions are available in two state-of-the-art platforms — the standalone Tellabs® 3100 Voice Quality Enhancement System and the Tellabs® 5500 Digital Cross-Connect System (DCS) Integrated Voice Quality Enhancement (iVQE).

Tellabs VQE Solutions vs. AMR issues

In a noisy environment, AMR HR calls encounter voice quality problems that can be mitigated with a Tellabs VQE product. A Tellabs study showed that the voice quality of AMR HR calls can be improved by Tellabs VQE products, giving operators the ability to deploy AMR HR in order to achieve capacity gains while still maintaining expected voice quality (Figure 8).

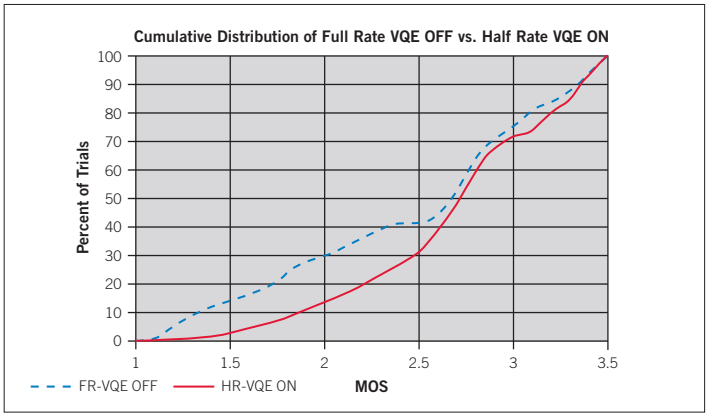


Figure 8. Performance comparison of AMR FR VQE off to AMR HR VQE on.

Alternatively, Tellabs conducted an additional study to show that VQE improves voice sustenance to BER in noisy environments. As illustrated in Figure 9, while using the AMR HR codec with Tellabs VQE products, packet errors can be sustained up to 17% and maintain the same MOS value. When reasonable voice quality is offered by the network, Tellabs VQE solutions can expand network coverage and capacity by retaining calls on HR longer.

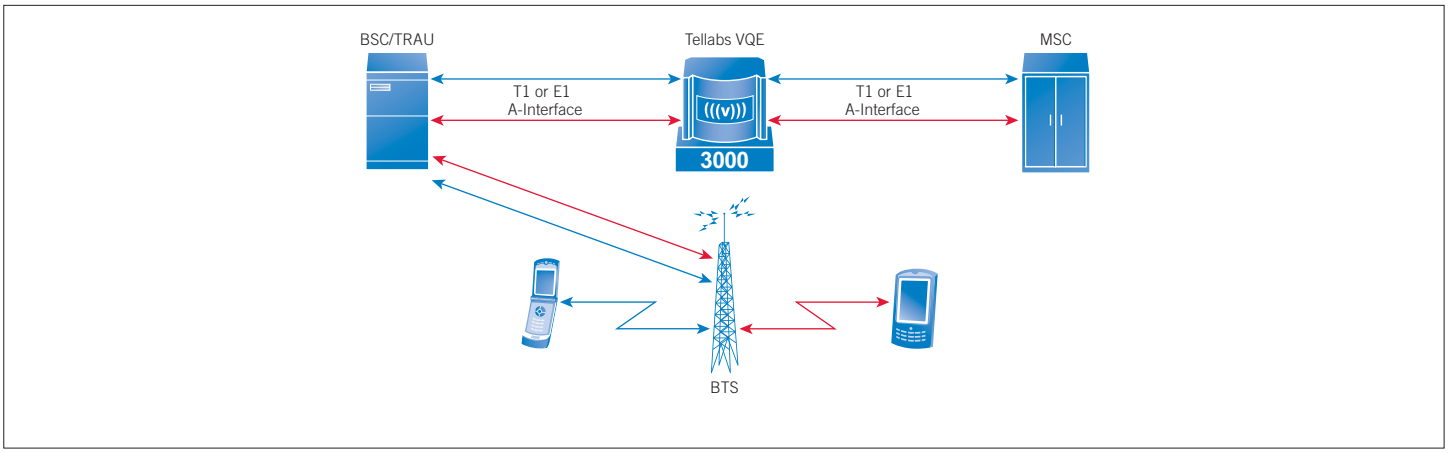


Figure 7. Network-based VQE offers a consistently improved user experience across the network.

Conclusion

An advanced network-based Tellabs VQE solution from Tellabs can augment AMR codec deployment by enabling operators to roll out AMR HR and benefit from full capacity and coverage gains without compromising voice quality.

The 3GPP introduced AMR codecs that provide excellent link adaptation schemes in poor RF conditions. The codecs achieve this efficiency by combining lower bit rate speech coding and robust error protection mechanisms in channel coding.

The 3GPP also highlighted some drawbacks of AMR HR codec performance in noisy conditions and generated handset performance guidelines for noise suppression mechanisms. Due to the subjective nature of the voice quality evaluations, these guidelines have not been strictly adhered to or closely monitored.

Operators tend to limit the rollout of AMR codec to certain speech rates in order to minimize the impact on voice quality, thereby using spectrum and network infrastructure inefficiently.

Tellabs network-based VQE solutions address AMR codec issues by offering echo cancelling, noise reduction and level control functions. This technology augments the deficiencies of AMR HR and helps operators achieve spectrum efficiency, capacity improvements and coverage gains by employing advanced digital signal processing mechanisms to remove speech impairments. Figure 9 details the simulation results indicative of MOS improvements in increasing packet error environments. This performance indicates that the RF characteristic selection criteria can be modified to enable more AMR HR usage without impacting MOS scores.

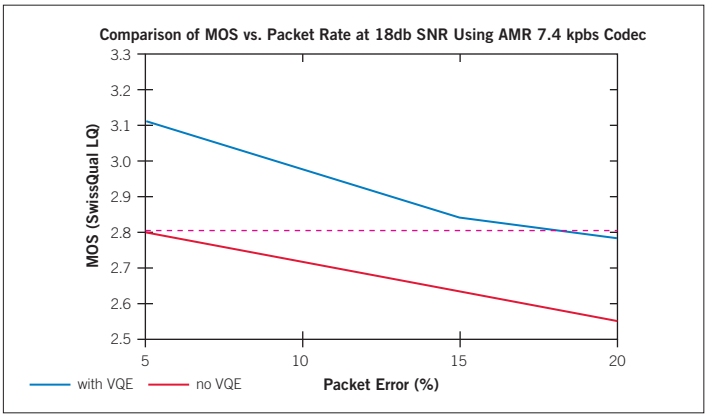


Figure 9. Comparison of packet error rate with MOS while using AMR HR codec.

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