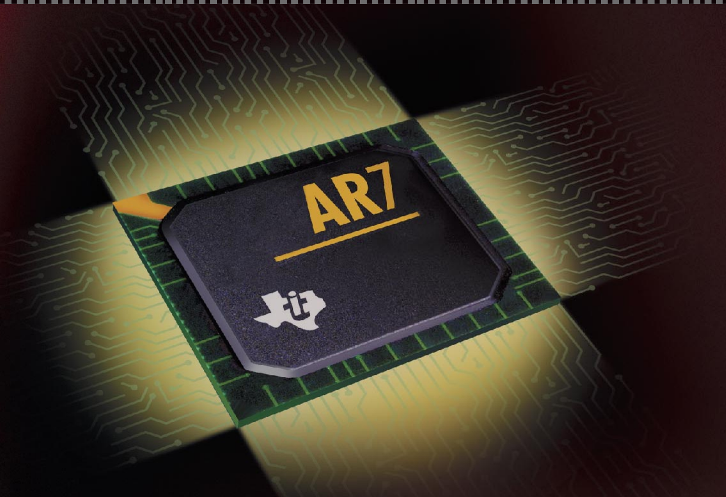
Texas Instruments

Dynamic Adaptive Equalization™



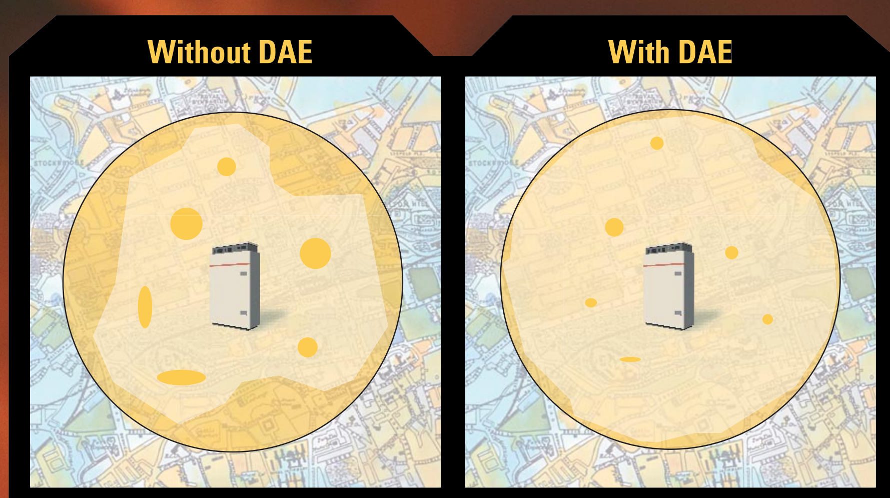
AR7 PERFORMANCE ENHANCEMENTS

The AR7 platform features Dynamic Adaptive Equalization (DAE) technology, an integrated set of performance-optimizing enhancements fundamental to the chips' advanced architecture. DAE allows the AR7 to compensate for the predominant impairments that plague DSL local loops in a fluid, adaptive manner. This technical brief highlights the following components of DAE:

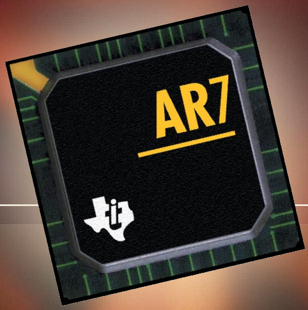
- **Programmable Tx and Rx filters**
- **Switchable hybrid**
- **Echo cancellation**
- **Configurable equalization structures**

These DAE physical layer enhancements, when applied to the AR7 platform, result in significant improvements to rate and reach performance, as well as interoperability, for manufacturers, service providers and end users. Service providers who have deployed AR7-based CPE modems have experienced extended carrier service area (CSA) coverage.

- IDEAL SERVICE PROVIDER COVERAGE AREA FROM CENTRAL OFFICE
- ACTUAL COVERAGE AREA
- UNSERVICEABLE AREAS RESULTING FROM BRIDGE-TAPS, ETC.



We've supercharged your DSL performance.



Predominant Loop Impairments addressed by DAE:

INTERSYMBOL INTERFERENCE (ISI)

As symbols pass through transmit filters, the channel and receive filters, they are effectively "smeared" together in time. The interference resulting from the overlapping of symbols, ISI, typically extends beyond the cyclic prefix length in ADSL, resulting in a reduction in the data rate.

BRIDGED TAPS

Bridged Taps refer to an unterminated connection of another local loop to a primary local loop, forming a transmission line stub with adverse effects on the line impedance and transfer function. Many loops contain bridged taps, whether in the local loop or customer premises wiring.

RADIO FREQUENCY INTERFERENCE (RFI)

RFI describes the intrusion of foreign signals, such as AM radio, into the ADSL band, and is caused by an imperfect balance on the twisted-pair wire. RFI results in a data rate reduction across a large number of subchannels.

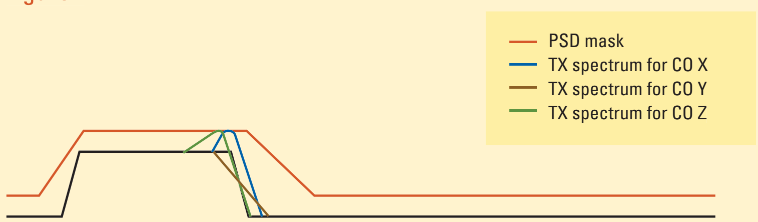
ECHO

ADSL is a full-duplex communication system, meaning that both upstream and downstream signals are transmitted simultaneously through the same transfer medium. It is the task of the receiver to separate the locally transmitted signal (echo) from the far-end received signal.

Programmable Tx and Rx Filters

Every CPE modem encounters different channel and system environments, so each one requires unique filter settings to attain optimum performance. These adaptive settings are essential in dealing with varying channel conditions, as well as the different DSLAM requirements for the transmit and receive channels. Texas Instruments' AR7 platform features programmable coefficients for digital pre-compensation, band-split and power spectral density (PSD) shaping filters, as well as multiple corner frequencies for analog filters—resulting in ideal system interoperability and greatly enhanced data rates.

Figure 1



Improved interoperability through the use of active transmit filter profiles.

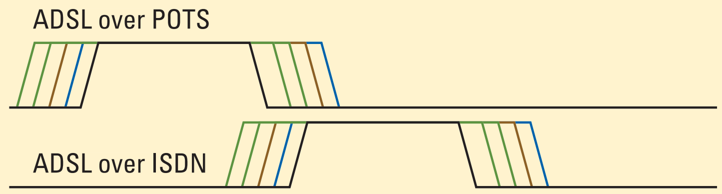
TRANSMIT FILTER PROFILING

AR7 determines the transfer filter profile best suited to the characteristics of the involved DSLAM *(see Figure 1)*.

PSD COMPLIANCE

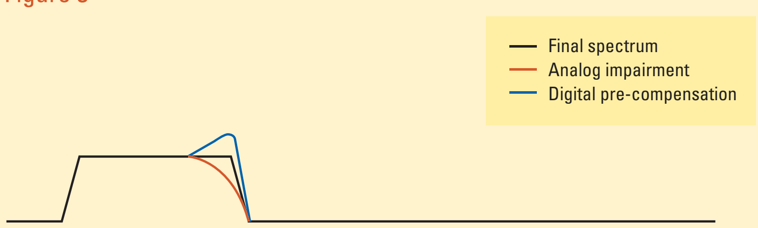
AR7 accommodates a wide range of PSD masks for Annex A, Annex B, Annex C, ADSL2/ADSL2+, All-Digital Loop (ADL), Reach-Extended ADSL (READSL) and more *(see Figure 2)*.

Figure 2



Flexible analog corner frequencies and programmable digital filters allow for multiple PSD masks.

Figure 3



Filters pre-compensate for the effects of analog impairments.

DIGITAL PRE-COMPENSATION

In addition to accommodating analog process variations, programmable filters enable digital pre-compensation for transmit transfer function variations caused by impedance mismatch *(see Figure 3)*.

Switchable Hybrid

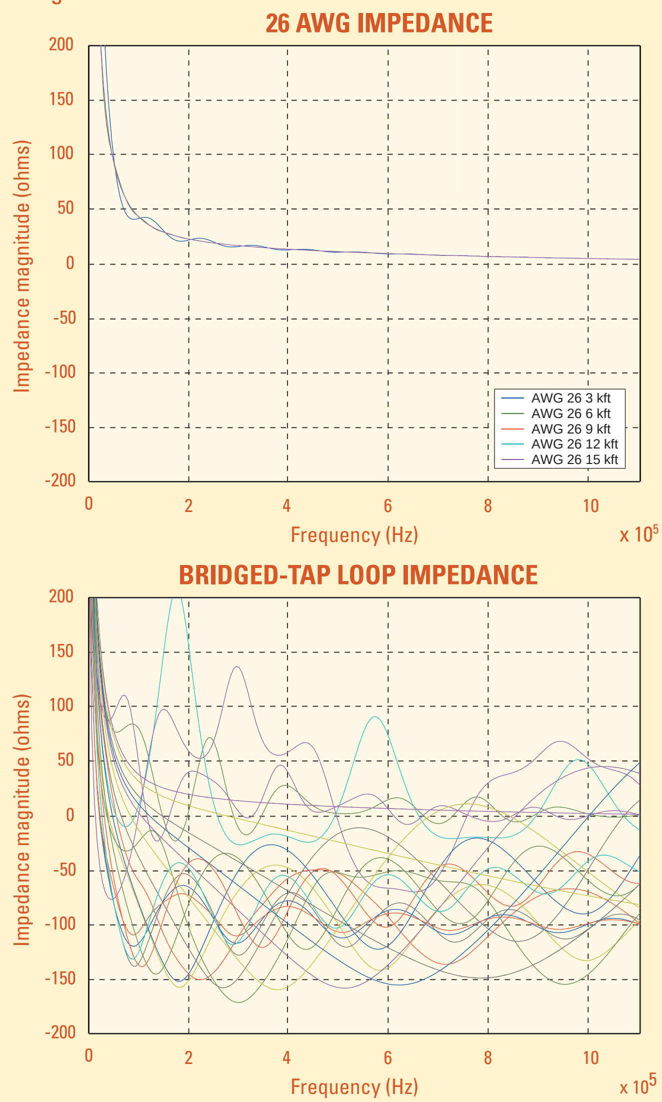
A hybrid acts as an analog echo canceller that subtracts the transmitted signal from the receive path once the signal has been filtered by the transmit echo transfer function. In practical systems, this transfer function can only be approximated since it is highly dependent on the line impedance, which varies greatly depending on the loop characteristics *(see Figure 4)*. AR7's solution improves the matching process by employing multiple hybrids that can be switched in or out, or combined, resulting in improved echo rejection over a wider range of loop conditions.

AR7 hybrids are designed specifically for the loop characteristics of the region in which the unit will be deployed. Upon equipment initialization, AR7 determines which hybrid is the best choice for the present loop environment. Unlike single fixed hybrids, which ultimately sacrifice data rate and loop plant coverage, the switchable hybrid solution offers an adaptive flexibility that greatly enhances the AR7's performance *(see Figure 5)*.

Echo Cancellation

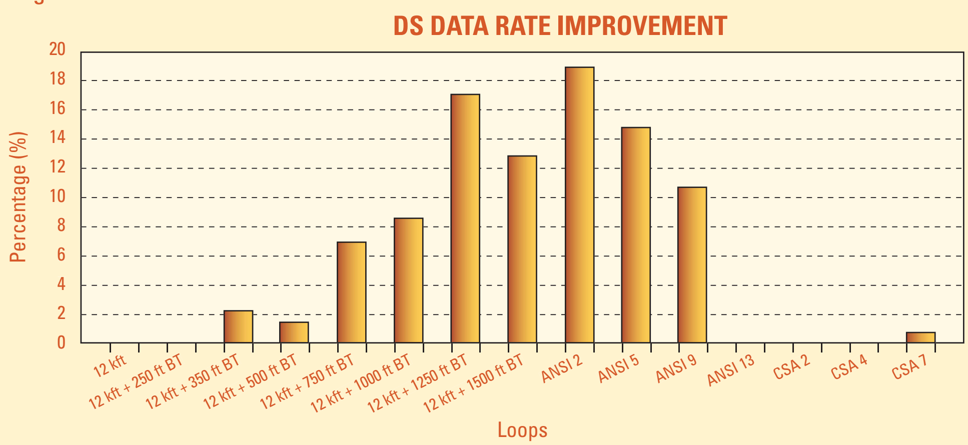
Echo Cancellation (EC) is used to eliminate the echo signals that were not removed by hybrid matching. The basic EC structure assumes that the echo is a filtered version of the transmitted signal. Echo cancellation is then performed by subtracting the output of a filter fed by the transmitted signal from the received signal. This filter is identified during training to approximate the echo channel.

Figure 4



Switchable hybrids address a broad range of impedence scenarios, including straight (top) and bridged-tap (bottom) loops.

Figure 5



Performance testing of AR7 with a fixed hybrid versus AR7 with a switched hybrid. TI test results prove significant improvements in downstream data rate when employing switchable hybrid technology, especially on bridged-tap (BT) loops.

Configurable Equalization Structure

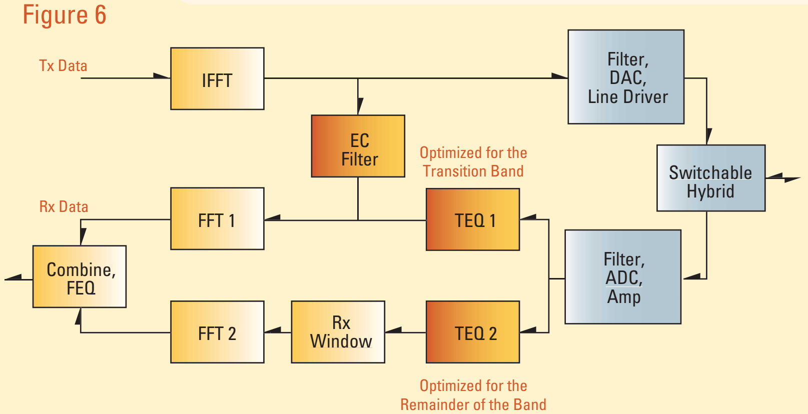
Typically, no single equalization structure offers optimum performance for all possible channel conditions encountered in real DSL environments. AR7's configurable architecture offers clean implementation and high system utilization for four different structures using the same basic time domain equalizer (TEQ) and fast Fourier transform (FFT) components, but with the addition of simple delays, downsampling and routing. The four possible equalization structures are:

> single-path **> dual-path** **> oversampled** **> double-rate**

Use of these structures improves the equalization performance, enabling further fine-tuning using DSP algorithims.

ADSL systems use a cyclic prefix (CP) to minimize the effects of ISI. If the impulse response of the effective channel (including transmit and receive filters) is shorter than the cyclic prefix, no ISI occurs. However, this is not the case in most practical systems. Therefore, a TEQ is used to shorten the effective channel length.

Figure 6



Dual-path receiver configuration.

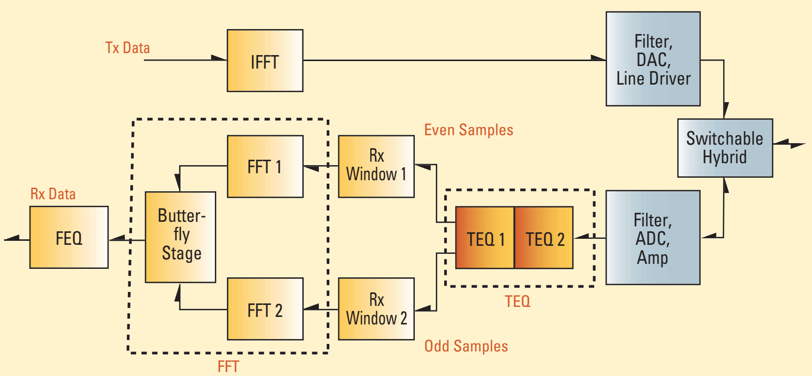
DUAL-PATH TEQ

A dual-path equalization architecture allows the equalization structure to be optimized for different parts of the communication channel. For multicarrier systems such as ADSL, this allows one equalizer to be optimized for the transition band (where high ISI and echo are strong) and a second equalizer for the remainder of the band (where mild ISI, low echo, and possible RFI dominate performance). Afterwards, the outputs of the two paths are compared, and the better of the two is selected as the output for the subchannel *(See Figure 6)*.

RECEIVER WINDOWING

Receiver windowing picks up after the TEQ in compensating for RFI. Figures 6 and 7 show the use of receiver windowing for ***dual-path*** and ***double-rate*** receiver configurations, respectively. Receiver windowing exploits the information in the cyclic prefix to form a window with sidelobes that decay faster than those of the rectangular window. Therefore, even if RFI appears after training, the modem still exhibits a greater immunity to its detrimental effects.

Figure 7



Double-rate receiver configuration for ADSL2+.

We've supercharged your DSL performance.

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AR7 Solution Family homepage: **www.ti.com/AR7vwi**

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