Key Requirements for Multi-Tuner Automotive Radio Designs

Standard car radios, first introduced by Motorola more than 80 years ago, have evolved over the decades into sophisticated infotainment systems capable of reproducing music and other audio content from a wide array of sources including AM and FM radio signals, CDs, portable media players, USB flash drives, SD cards and Bluetooth audio. Many of today's high-end infotainment systems contain secondary tuners used to receive data for traffic information for navigation systems. In addition, the use of dual antenna systems in cars is a growing trend in Europe and the US where FM phase diversity is being adopted for high-performance FM reception systems.

The radio components used in today's vehicles need to be cost-effective while meeting rigorous automotive levels of performance. With the advent of multi-tuner automotive infotainment systems, car radio developers must now consider a wide range of performance requirements and new technologies in their designs. Let's take a closer look at some of these key requirements.

Sensitivity

Sensitivity refers to an automotive radio tuner's ability to pull in weak stations. If you live in a rural area away from the transmitters of most radio stations, the sensitivity of a tuner is of great importance. Current car radio designs typically require microvolt level sensitivity, enabling the car radio to pull in an extremely weak signal and extending its ability to tune into a station dozens of miles away. Silicon Labs' state-of-the-art Si476x low-noise amplifier with -3.5 dBµV sensitivity can pull in a signal at 0.06 microvolt, which extends its ability to tune in to a station up to 100 miles away.

Selectivity and Dynamic Bandwidth Control

Selectivity refers to a tuner's ability to receive a weak station in the presence of stronger stations at small frequency offsets. This is especially important for receivers in crowded FM spectrums in urban environments. As shown in Figure 1, the automotive listener may want to tune in to a weak desired station while a closer station may present a stronger undesired signal. Being able to "select" the correct station is very important for listener satisfaction.

An important performance requirement, especially for European markets where the adjacent channel blockers can be as close as ±100 kHz for FM broadcast in border regions, is adjacent channel selectivity. This refers to suppression of signals ±100 kHz away from the tuned frequency. The Si476x tuner comes with 65 dB selectivity with ±100 kHz blockers, setting a new standard for single-chip automotive tuners. This exceptional selectivity is realized by a powerful state-of-the-art radio DSP algorithm that dynamically optimizes the desired channel bandwidth by gauging several signal metrics including adjacent and alternate channel conditions, narrowing the channel bandwidth in the presence of strong blockers.
Third-Order Intercept Point (IP3)

IP3 is a figure-of-merit measure of the linearity of the tuner. Higher IP3 means better linearity and less distortion. The most severe distortion is third-order intermodulation (IMD3) distortion resulting from two close-in blockers that show up on-channel on the desired station. In crowded FM spectrums that are common in urban markets, the blockers are too close to the desired station to be easily filtered out. To minimize third-order distortion products, the IP3 performance must be increased. Tuners with low IP3 will require very expensive high Q tracking filters to avoid IMD3 break-in, resulting in an extremely unpleasant experience for the listener. As shown in Figure 2, low linearity can result in two high-power stations interfering with a desired station.

The Si476x tuner features IP3 of 117 dBµV coupled with sensitivity at -3.5 dBuV at full RF gain. This IP3 and sensitivity performance level enables a dynamic range of 79 dB IMD, which is the best in its class, providing the utmost protection against IMD3 break-in with no external filtering blocks.
Alternative Frequency (AF) Check

In Europe, AF check is an option that allows the car radio tuner to tune to a different frequency that provides the same station when the first signal becomes too weak while moving out of range, as illustrated in Figure 3. This feature is often used in European car radio systems and is enabled by radio data system (RDS) technology (i.e., the AF list is transmitted via RDS data). Higher end cars use a dedicated background companion tuner to scan the AF list, providing AF station metrics to the host to decide when to jump to the AF station when the primary station becomes compromised. In cost-sensitive radios that use one tuner instead of two tuners to reduce cost, the primary audio tuner is tuned to the AF station to qualify the AF station and is re-tuned to the primary station without causing a perceptible break in the audio. The maximum time accepted in executing the AF check operation is under 10 ms. Most tuners in the market today are able to only qualify the AF station’s RSSI. The Si476x tuner is able to perform an AF check operation in less than 8 msec and to qualify four station metrics including received signal strength indication (RSSI), signal-to-noise ratio (SNR), frequency offset and multi-path interference.

Figure 3. Automotive Tuner with AF Check Capabilities in Europe

FM Multipath Handling and Channel Equalizers

Multipath interference is the bane of FM radio reception in mobile environments especially at high speeds. Multipath distortion is caused when two or more radio signals broadcast from the same source arrive at a receiver at different times and with different phases and attenuation levels due to reflections of the signal from various objects in the surrounding environment (see Figure 4). Prior to arriving at the receiver, the radio signal can experience changes in amplitude and phase due to two types of multipath fading: flat and frequency-selective. In urban environments, reflections from close-in objects such as buildings result in short-delay multipath fading, causing wideband deep fades. In this scenario, all spectral components of the signal experience amplitude attenuation simultaneously (flat fading) leading to harsh audio pops and drop-outs. In turn, long multipath delay (frequency selective fading) arises due to reflections from objects several kilometers away such as distant hills and tall buildings. In this scenario, certain spectral components will be attenuated, causing deep notches in the channel and leading to audio distortion.

The traditional approach is to mitigate the effects of multipath distortion with techniques such as blending back to mono audio from full stereo audio, deploying low-pass audio filters (hi-cut and hi-blend), attenuating the audio level when there are harsh pops due to severe multipath, and as the last resort, soft muting. All of the above mitigation engines run on the Si476x tuner autonomously, activated by signal quality metrics that are continuously monitored by the tuner.
The Si476x tuner incorporates an FM channel equalizer designed to cancel frequency selective multipath fading, thus yielding audio with minimal distortion. The equalizer’s adaptation algorithm continuously seeks to restore spectral components attenuated due to frequency-selective fading effects, thus restoring the signal even as the vehicle travels through multiple fading situations. The result is reduced audio distortion and a lower level of sound-compromising mitigation applied to the audio such as stereo-mono blend and hi-cut/hi-blend.

Figure 4. Channel Equalizer Restoring Signal Loss Resulting from Frequency Selective Multipath Fading

FM phase diversity

In recent years automotive OEMs – especially those in Europe – have moved away from passive whip rod antennas and adopted glass/patch active antenna systems. However, FM radio reception becomes compromised with small glass antennas. With dual antenna/phase diversity tuner systems, OEMs circumvent this issue by combining two antenna signals, which provides more signal and significantly improved resistance to multipath fading.

Dual-tuner phase diversity systems with built-in channel equalization can be implemented by using high-performance automotive receivers such as the Si476x to address both flat and frequency-selective fading. In essence, the dual tuner outputs are combined to alleviate fading, which greatly improves audio quality. In an antenna phase diversity system, the RF signal is received by two uncorrelated antennas spaced at an optimum distance from each other, and they are connected to two tuners tuned to the same frequency. With this dual-tuner design, the signal propagation path at one antenna location may experience a deep fade while the other signal propagation path at the other antenna location does not (see Figure 5).
The two-antenna phase diversity solution enabled by the Si476x receiver allows multiple antenna outputs to be combined to minimize poor signal reception caused by flat fading. The two receivers use a common reference clock to ensure that they are tuned to the same channel frequency. An innovative, patented inter-chip data bus connecting two Si476x receivers is used to stream the IF signal and associated signal quality metrics from the secondary receiver to the primary receiver. The two IF signals are phase aligned and combined in the primary receiver using proprietary phase diversity algorithms. The combined IF signal is subsequently channel-equalized, FM-demodulated, MPX-decoded and signal-conditioned in the primary receiver. The stereo audio output is then sent to the system’s audio signal processing unit.

Figure 5. Impact of Short-Term Flat Fading.

A dual-tuner, two-antenna/phase diversity system, coupled with an integrated channel equalizer, enables significantly improved FM radio reception and yields higher immunity to severe multipath and weak signal conditions.
AM/FM HD Radio Technology

Developed and licensed by iBiquity Digital Corporation, HD Radio™ technology is used by AM and FM radio stations to transmit audio and data through a digital signal in conjunction with analog signals. The US Federal Communications Commission (FCC) has selected HD Radio technology as a digital radio standard for the US market, and it is currently the only digital radio system approved by the FCC for digital AM/FM broadcasts in the US. In essence, HD Radio technology upgrades broadcast radio from analog to digital. Broadcasters that adopt HD Radio technology can provide consumers with many benefits that improve their listening experience such as CD-like digital audio quality and useful data services.

HD Radio digital radio broadcast technology is gaining traction in the US automotive market. Previously relegated to high-end cars, HD Radio is now moving into mid-range automotive radio platforms in the US. To date, more than 20 automotive brands have announced HD Radio technology as a factory-installed infotainment feature. Leading automotive OEMs that have adopted HD Radio include Ford, Volvo and BMW to name a few. It is estimated that by 2015 more than 50 percent of all cars shipping in the US will support HD Radio reception.

Figure 6. US Car Radio Design for AM/FM HD Radio Reception with Si476x Receiver

iBiquity has certified Silicon Labs’ Si476x tuner family (as shown in Figure 6) to provide AM/FM HD Radio tuner outputs and reception with compatible HD Radio demodulator ICs. The Si476x family also supports all worldwide broadcast radio bands including AM/FM, college FM, longwave (LW), shortwave (SW), NOAA weather band and FM RDS decoding.

Summary

Today’s consumers expect a CD-quality audio experience from their car radios. Automotive OEMs and Tier 1 suppliers understand this trend and are responding by designing sophisticated infotainment systems that incorporate multiple tuners to deliver FM phase diversity reception, receive RDS data for info-navigation systems and support digital radio standards such as HD Radio technology. Today’s challenging broadcast performance demands require next-generation automotive tuners to enable a superior in-vehicle audio experience.