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Designing High-Performance, Cost-Effective Car Radios with CMOS-Based AM/FM Automotive Receivers

High-growth economies such as Brazil, Indonesia, India and China have an emerging middle class and rapidly growing automotive markets. The vehicle retail price in these markets must be relatively low, putting cost pressure on components in these vehicles. Additionally, automotive markets in developed economies such as the United States, European nations and Japan are also seeing an increased demand for cost-sensitive solutions after the global financial crisis that began in 2008. With AM/FM radios available in almost every car, truck and van, radio module manufacturers are motivated to seek lower cost solutions that meet traditional automotive levels of performance.

Traditional technologies used in automotive AM/FM tuners are typically BiCMOS tuners with a 10.7 MHz IF tuner architecture. This technology/architecture delivers on radio reception performance, but the process and architecture are cost prohibitive for mixed-signal architectures where RF circuits are integrated with digital processing engines such as DSPs and microcontrollers in a monolithic circuit to deliver fully processed audio outputs.

Digital low-IF CMOS AM/FM receivers very much fit the bill due to the much lower cost points of CMOS foundries and the use of a digital low-IF tuner architecture. Digital low-IF AM/FM receivers have been in use in the handset and portable media player markets for a number of years. In these markets power consumption and cost are highly critical considerations while in the automotive market the tuner performance requirements are usually much higher due to mobile reception and higher expectations of performance.

Let's examine several key requirements for an AM/FM radio receiver optimized for automotive applications.

RF Dynamic Range

In crowded FM spectrums that are very common in urban settings, the abundance of radio stations can overwhelm the radio receiver tuned to a desired station whose signal strength is relatively weak, as shown in Figure 1. The most severe and common non-linear distortion resulting from strong interferers is third order inter-modulation (IMD3) distortion resulting from two strong close-in blockers that show up on-channel on a weak desired station tuned to.

In many applications an external tracking filter is used on the front end of the receiver to attenuate the blockers. This technique, however, is costly in terms of components and PCB real estate. In crowded FM spectrums the blockers are too close to the desired weak station to be easily filtered out. To minimize IMD3 distortion products, the dynamic range of the receiver front end must be adequate. Tuners with low dynamic range will require expensive high Q tracking filters to avoid IMD3 break-in, which can be an extremely unpleasant experience for the listener. A highly linear receiver with high dynamic range typically over 75dB is effective in most field conditions. With the cost constraints, a receiver with intrinsic dynamic range without the aid of an external tracking filter is highly desirable as it maintains performance while reducing system cost.

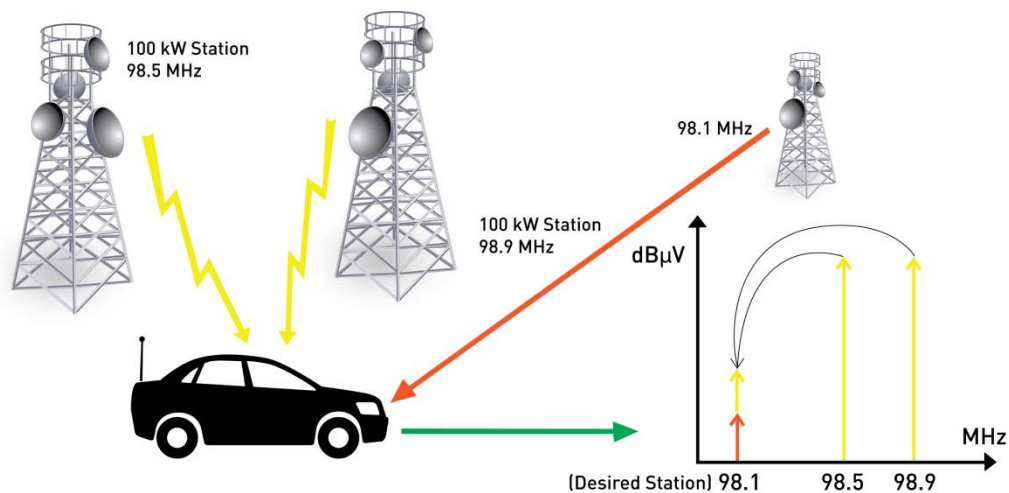


Figure 1. RF Dynamic Range Protection

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 (see Figure 2). This is especially important for receivers in crowded FM spectrums in urban environments. An important performance requirement, especially for European markets where the channel spacing is 100 kHz for FM broadcast, is adjacent channel selectivity, which refers to suppression of signals $\pm 100\text{kHz}$ away from the tuned frequency and which is usually no better than 30dB in many tuners found in the low-cost category.

While 30 dB selectivity performance may be adequate for many field conditions, there are many situations in the world in which a listener is tuned to a station broadcast from a distant location while driving past towers broadcasting multiple stations in the local region. In this scenario, much higher selectivity is required. In many radio receivers, the solution is realized with high dynamic range and an agile dynamic channel bandwidth control engine for adjacent channel suppression. With digital Low-IF integrated receivers, dynamic channel bandwidth control is readily achieved with powerful state-of-the-art radio DSP algorithms that dynamically optimize the desired channel bandwidth by gauging the adjacent and alternate channel conditions, narrowing the channel bandwidth in the presence of strong blockers.

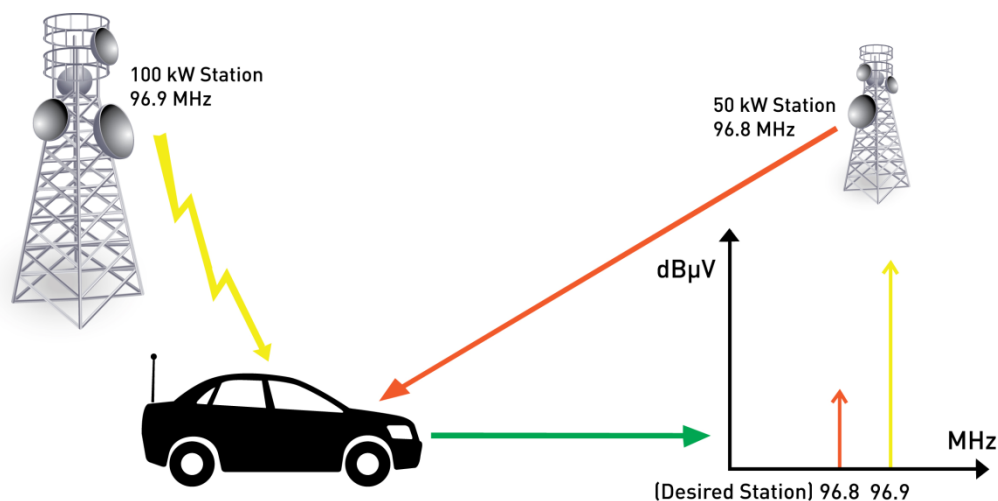


Figure 2. FM Dynamic Channel Selectivity

Sensitivity

Sensitivity refers to a 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 will be of great importance. With current car radios, the performance requirements are typically microvolt level sensitivity, allowing the car radio to pull in an extremely weak signal and extending its ability to tune into a station dozens of miles away. The cost pressures call for an integrated receiver to support this level of sensitivity without an external low noise amplifier (LNA). This sets a high bar of performance for integrated CMOS receivers whereby the RF front end is integrated on the same monolithic IC as the high-speed digital processing engines.

Alternative frequency (AF) Check

In Europe, alternative frequency (AF) technology (represented in Figure 3) is an optimal choice that allows the car radio tuner to tune to a different frequency that provides the same station when the first signal becomes too weak when moving out of range. This technology is often used in European car radio systems, enabled by radio data system (RDS) technology where the AF list is transmitted via RDS data.

In higher end cars, a dedicated background companion tuner is used to scan the AF list, providing AF station metrics to the radio to decide when to jump to the AF station when the primary station becomes compromised. In cost-sensitive radios where two tuners can be too expensive to implement, the primary audio tuner is tuned to the AF station to qualify the AF station and re-tuned to the primary station without causing an audible break in the audio. The maximum time accepted in executing the AF check operation is under 10 msec. More time than this can result in an audible break.

The AF switching strategy depends on a number of signal quality metrics including received signal strength indicator (RSSI) and signal to noise (SNR). The benefit of using an integrated digital receiver is the availability of the high-speed digital signal processing engine to execute two operations: 1) RDS demodulation and decoding to provide the AF station list; and 2) expediting the signal quality metric calculations to meet the rapid AF check times.

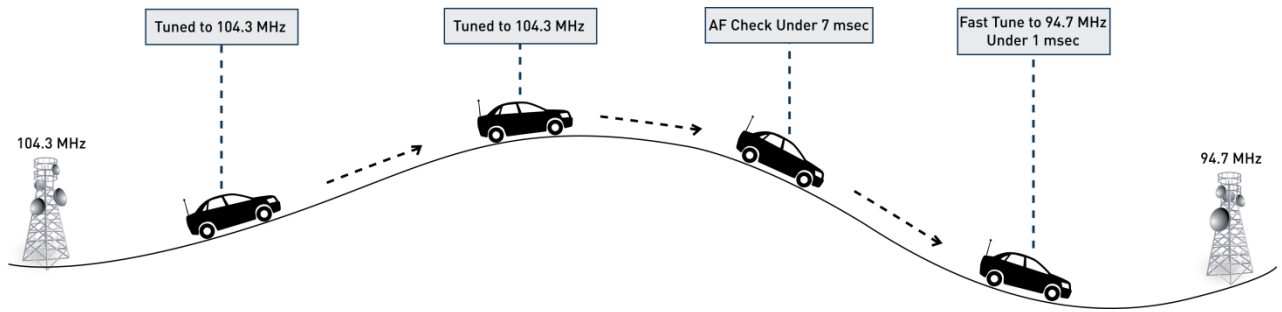


Figure 3. Alternative Figure Checking

In summary, continuing cost pressures in the global automotive market are driving the development and deployment of highly integrated and innovative CMOS radio receiver IC solutions that will provide significant cost savings in transitioning from traditional architectures and analog-centric semiconductor processes typically employed for car radio tuners.

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