

Reception Requirements for Automotive Radio Systems

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ABSTRACT

Automotive manufacturers are increasingly demanding for better quality reception from radio designers to provide enhanced audio listening experience for their customers. Audio content can be provided from many sources today, including AM/FM signals, CDs, SD cards, USB flash drive, etc. The modern AM/FM receiver incorporates sophisticated DSP algorithms for signal reception and must not sound dramatically inferior to other audio sources. This paper reviews a few key reception environments that the mobile receiver must cope with, in able to provide good quality reception and to meet the required mobile receiver specifications.

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INTRODUCTION

In an ideal wireless communication channel link, the mobile antenna receives the transmitter signal without any distortions or signal alterations. In a realistic communication link however, nature and spectrum crowding make it much more difficult to receive radio frequency (RF) signals reliably [1]. The key reception challenges include adjacent channel, sensitivity, Image rejection, Third-order Intermodulation products distortion, and multipath distortion.

Sensitivity is a measure of the receiver's ability to receive weak RF signal from far away stations. Selectivity is the receiver ability to suppress strong channels nearby in the AM/FM spectrum. Image rejection became an issue in modern FM receivers due to the change in Intermediate Frequency (IF) from 10.7 MHz to low-IF, a few hundreds kHz. Third-order intercept point is determined by the linearity of RF front-end of the receiver.

Multipath distortions are the most problematic for the mobile receiver. The path between transmitter and receiver adds noise and superimposes an amplitude and phase response caused by the filtering effects of the multitude of paths the signal can take in traveling between the transmitter and receiver. Multiple signals from the same tower received at the mobile antenna with different amplitudes, phases and delays cause multipath distortion.

SENSITIVITY

Sensitivity is the minimum magnitude of received signal (from distant tower as shown in [Figure 1](#)) required to produce a specified output signal having a specified signal-to-noise

ratio, or other specified criteria (i.e. SINAD, BER, etc). A sensitivity of 2 to 4 dBμV is typical for a mobile FM receiver for 26 dB SINAD (22.5 kHz deviation). A 9 to 11 dBμV is typical for a mobile AM system for 26 dB SINAD (30 % modulation).

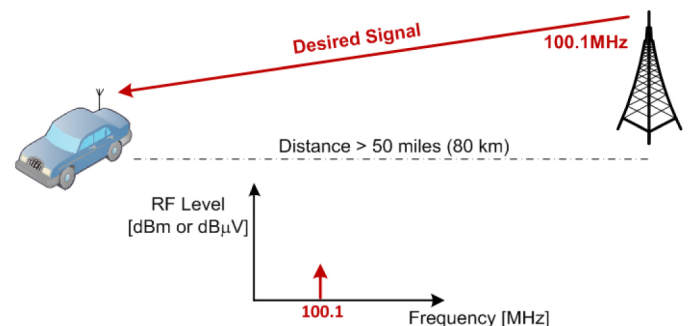


Figure 1. Received weak RF signal from distant tower

SELECTIVITY

Selectivity is the capability of the receiver to receive weak signal (from distant tower) in the presence of a strong adjacent signal (from nearby tower, [Figure 2](#)). FM stations channels are spaced ± 100 kHz apart in Europe and Asia. In the United States, FM stations channels are spaced ± 200 kHz apart. That makes the reception in Europe and Asia more challenging in the case of adjacent channel selectivity. In modern FM receivers, selectivity of 30-60dB (even more is possible) can be achieved by DSP algorithm, with maintaining acceptable distortion level. As long as the ADC

has enough linear range, the DSP can achieve the required selectivity by utilizing dynamic bandwidth filter or a bank of defined filters with very sharp roll-off not practical with existing analog filter technology. AM stations channels are spaced ± 10 kHz apart in the United States and ± 9 kHz apart in the rest of the world.

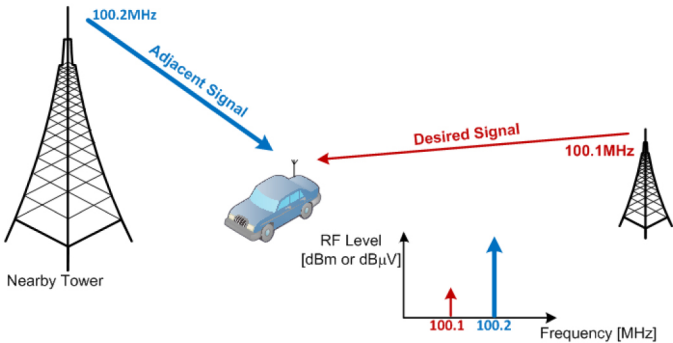


Figure 2. Selectivity Scenario - Received weak RF signal in the presence of strong adjacent channel

THIRD-ORDER INTERCEPT POINT (IP3)

Intercept Point (IP: 2nd or 3rd or 4th, etc.) is a mathematical concept used as a measure of the linearity of the RF front-end of the receiver. The mobile receiver linearity is critical because the signal conditions are constantly changing as the vehicle moves. The receiver circuits should be designed as linear as possible to handle high amplitudes of input signals. Two-tone test is commonly used to measure the linearity of a receiver, see Figure 3. In particular, IP3 is a key intercept point specification based on measurement and experience with practical systems. The higher the IP3 number the better the linearity. One of the observed severe cases in the field is the Third-order Intermodulation Distortion products (IMD3) caused by nearby towers in crowded FM spectrum as shown in Figure 3. In this case, the RF front end should be linear enough so the IP3 product will not be higher than the desired signal. The Automatic Gain Control (AGC) will eventually be triggered in order to reduce all strong signals including the desired. A good AGC system will attenuate the undesired signals enough to reduce the IP3 distortion but will maintain enough usable (and detectable) desired signals. A greater than 125 dBμV (+18 dBm) for input IP3 is a typical value for mobile FM receiver. For AM receiver, input IP3 should be greater than 130 dBμV (+23 dBm).

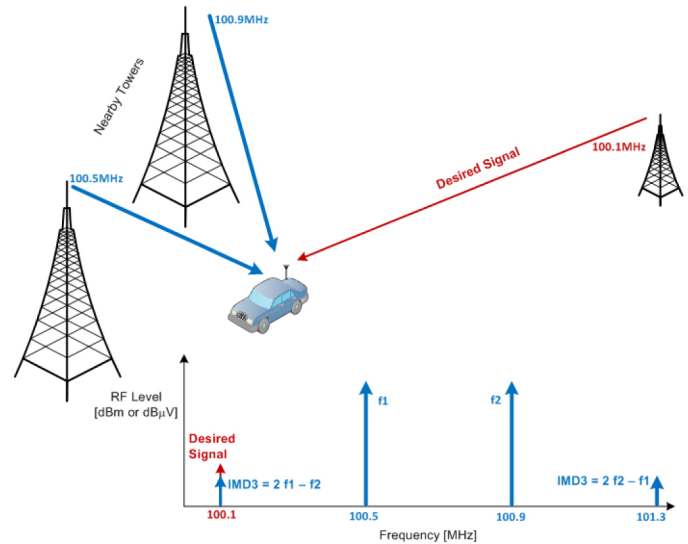


Figure 3. Third-order Intermodulation scenario

MULTIPATH

Multipath distortion is caused when two or more signal rays converge upon a receiving antenna at significantly differing times. The mobile antenna acts like a summer; it adds direct and reflected signals. This “misalignment” of several delayed replicas of the direct signal causes distortion in the recovered audio. In an urban environment the RF signals experience changes in amplitude and phase due to short delay multipath. This will result in broadband signal fades of 30dB or more as the vehicle moves. Long delay multipath (or frequency selective multipath) is found in environments where reflectors are greater than 6 to 8 kilometers away. This can occur in cities with larger buildings as well as mountainous regions. In general, long and short delay multipath coexist creating frequency selective and broadband fading simultaneously.

Figure 4 shows a typical situation commonly referred to as an “urban canyon” where signal reflections are all relatively short (60 meters drive). Wavelength $\lambda_0 = 3$ meter for 100 MHz RF signal). Thus flat fading occur where the signal spectral components are all acted upon equally resulting in amplitude fluctuations that affect all signal frequencies the same.

In an FM broadcast environment flat fading results in dynamically varying signal strengths, which manifests as dynamically varying carrier-to-noise ratio (CNR) into the receiver demodulator. The end user hears audio signal-to-noise ratio (SNR) fluctuations that sound like “spits and pops.”

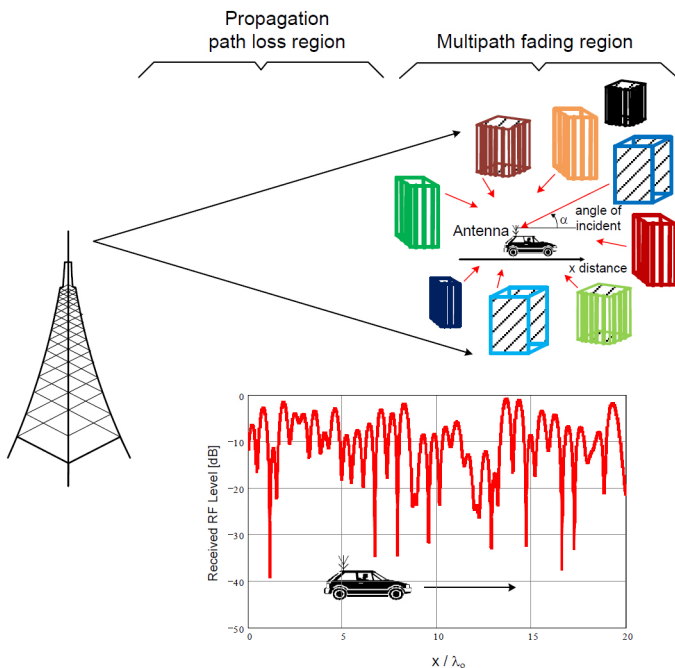


Figure 4. Multipath scenario in the city where the received signal experiences flat fading

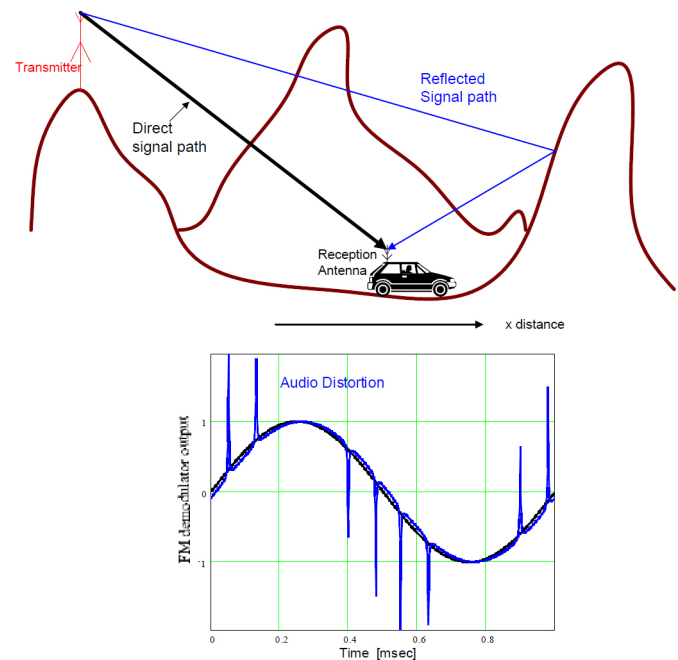


Figure 5. FM demodulator output shows audio distortion resulted from long-delay Multipath scenario in mountainous areas

When delay spreads are larger than 3 μsec the channel filter bandwidth starts becoming narrow relative to the signal bandwidth resulting in frequency selective fading.

Fig. 5 shows a scenario of a frequency selective channel in mountainous area. The direct path travels straight to the receiver antenna and experience some signal path-loss. The reflected path will experience signal path-loss and significant delay relative to the direct path. The end user hears harmonically distorted audio as shown in Figure 5 (30 μsec delay of the reflected signal path in this simulation example).

Multipath requires multi-antenna diversity systems to mitigate the distortion effects. The primary purpose of a diversity system is to reduce degraded reception performance caused by multipath propagation. This is often accomplished by the use of two or more uncorrelated FM receiving antennas. Diversity reception in mobile communication systems has been reported in past literature to reduce distortion due to fading.

In particular, a two-antenna phase diversity system has been implemented in many vehicles in recent years and showed major reception improvements in multipath situations in the field. The reader should refer to [2,3,4,5,6] for further details.

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