Field Measurement and Simulation of Electromagnetic Signals in a Semi-Anechoic Chamber

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Abstract: This paper presents the results of field measurements of strong and week electromagnetic signals in the 87.8MHz to 108MHz FM broadcast frequency band and the reproduction of the same signals in a semi-anechoic chamber with the objective of performing factory tests and calibration of FM stereo car radios.

Keywords: Electromagnetic Signals, Frequency Modulation, Semi-Anechoic Chamber, Parameter Measurement and Simulation.

1. Introduction

The proliferation of wireless devices in conjunction with the ever increasing users mobility have been stimulating the development of new applications, technologies and services that depends on the transmission of data to the mobile user.

Narrow-band digital data transmission using a sub-carrier of the FM broadcast channels operating in the 87.8MHz-108MHz band is a technique standardized since the decade of 1950. Known as SCA (Subsidiary Communications Authorization) as defined by the FCC (Federal Communications Commission), this technique consists of modulating audio or data signals in a sub-carrier whose frequency is above the ones used to transmit the main sound program of FM broadcast stations.

The RDS (Radiate Data Systems) system, for example, is a standardized technology used in Europe since 1990. Okumura [1] was the first one to present research results over the entire range of wave propagation concerning mobile users. In 1970, Okumura classified the propagation and path-loss characteristics in urban and suburban open areas with emphasis in the range of 200MHz to 1GHz. He also demonstrated the influences of the antenna type and height in the path-loss characteristics of the radio channels.

The results were summarized in graphic form known as ‘Okumuras’ curves, which were adopted by CCIR (now ITU-R) as recommendation 370.

In order to make full use of the RDS and similar technologies there’s a need to evaluate if a transmitted signal will be detected with enough field strength to become useful. In other words, electromagnetic waves should be detected with favorable signal-to-noise ratio so that its information content isn’t lost. In order to make that feasible a study should be performed to determine the electromagnetic field strength, the characteristics of the antennas being used as well as the sensitivity of the receiver.

Another important parameter is the signal level for appropriate station seek, so that the receiver can make the automatic tuning and thus achieve the best possible performance in areas of strong or weak signals. This operation has to be performed without making undesirable stops in spurious signals frequently generated by on-board car electronics and other external sources such as electric power lines. This operating condition is more evident in areas of weak signal reception where the AGC (Automatic Gain Control) circuit of the car radio increases the gain of the RF front-end causing the noise to be also amplified resulting in poor intelligibility of the original audio program.
2. Problem Formulation

The propagation mode of an electromagnetic wave and the losses that exist between two given points are influenced by channel frequency, distance from the source, wave polarization, size of the antennas, land contours, buildings, tower height, earth’s propagation constant, time schedule, seasons, and radiated power [4]. The propagation phenomenon becomes more evident and critical in the case of car radio application while the vehicle is moving.

When an automatic seek operation is performed in the 87.8MHz to 108MHz frequency band in areas of weak or strong signals if the reference level of seek is not correctly established the receiver will present an erratic behavior. The tuning process usually stops and the car radio locks in spurious signals, noise and side bands of FM broadcast stations that transmit in adjacent channels thus causing the demodulation of two or more different signals simultaneously. This undesirable condition is mainly noted when using the HMI-Human-Machine Interface which allows users to select the functions of the car radio through voice commands.

In order to achieve the best signal-to-noise ratio it is important to study the radio frequency spectrum in the field, and try to reproduce it in a test laboratory. With this intention in mind the methodology described below was established.

3. Problem Solution

3.1 Geographical Mapping of the Area

Two relevant areas for conducting the tests were characterized using altitude, latitude and longitude data provided by a GPS receiver. The first site was at 1941, Paulista Ave., in São Paulo-SP, longitude 4639.537 west, latitude 2333.606 south and characterized by a area of strong signals. The second site was at the parking lot of the Electro-Electronic Experimentation Division of Fiat Automobile plant, located in Betim-MG, Brazil and characterized by a area of weak signals. A RF scan was performed in accordance with [3] in both sites using the test setup shown in Figure 1.
Legend

- Undesirable Point of Tuner (Noise / Side Band);
- Station FM ok;
- Station FM Undesirable signal weak.

Figure 2: 1941, Paulista Ave, São Paulo-SP, Brazil.

Figure 3: Electro-Electronic Experimentation Lab, parking at Fiat Automobile, plant Betim –MG, Brazil.
3.2 Simulation in a Semi-Anechoic Chamber

Figure 5 presents a view of the semi-anechoic chamber used for generating the FM signals. It has the following characteristics:

- Magnetic fields: 20dB in 1 kHz, 56dB in 10 kHz and 100dB in 200 kHz;
- Electric field: 100dB in 200 kHz to 50MHz;
- Plane waves: 100dB in 50MHz to 10 GHz;
- Microwave: 100dB in 1GHz to 18GHz.

The far-field region inside the semi-anechoic chamber was determined for the generation of electromagnetic fields that correlate to the ones measured in the external test sites. The test vehicle was placed inside the enclosure. The test setup shown in Figure 1 was used again.

3.3 Generation of Electromagnetic Fields

Electromagnetic fields change their characteristic with the distance starting from the source. In the study of the RF fields three different regions are defined namely the near-field region, the transition field region, and the far-field region. The regions are delimited by spheres of radiation each one having different radius around the RF source’s antenna. The far-field region starts at distances of $R >> \frac{\lambda}{2\pi}$.

In the near-field region, the maximum and minimum values of the electric and magnetic fields don't happen in the same points along the wave propagation direction as it does in case of the far-field. The fields are not necessarily perpendicular and can't be characterized as plane waves. In the near-field region, the structure of the electromagnetic field is quite non-homogeneous.

In the far-field region the fields act as plane waves having the following characteristics: a) The vectors of the electric field $E$ and magnetic field $H$ are perpendicular to each other; b) The power density $S$ given in terms of $W/m^2$ represents the per unit area of equal power that is normal to the direction of propagation; and c) The power density in any point is calculated through the vector product of the electric and magnetic fields given by $S=E \cdot H$. The parameter $S$ is also known as the Poynting Vector. It represents the power density of the wave and gives the direction of propagation.

The expressions shown below give the relationship between the electric and magnetic fields and the Poynting Vector.

$$S = E \cdot H; \quad S = \frac{E^2}{377}; \quad S = 377H^2$$

The field intensity of the electric and magnetic fields varies inversely with the distance from the source and the power density $S$ varies inversely with the square of the distance from the source. During the test inside the chamber the transmitting antenna was installed at a distance $R >> \frac{\lambda}{2\pi}$ from car radio’s receiving antenna to simulate a far-field condition. The car radio’s antenna transmission line was established as a multiple of $\lambda$ of the generated test signal. The test signals were generated using 94.1MHz and 98.1MHz both using a level of 24.7dBµV for calibration of the radio. The test levels correspond to the ones found in the field measurements. The test results are presented in Figure 4.

The 94.1MHz signal with a level of 24.7dBµV corresponds to the FM station with the lowest receiver level and best signal-to-noise ratio and thus becoming the best candidate for an automatic seeking test operation (the methodology for choosing this specific signal/level isn't described in this paper). Frequencies received with levels below 24.7dBµV don't provided favorable signal-to-noise condition and offered poor intelligibility and so are undesirable during the automatic seek.
Figure 4 - Electro-Electronic Experimentation Lab. Parking lot at Fiat Automobile plant, Betim -MG, Brazil.

Figure 5 - Shielded semi-anechoic chamber at Fiat Automobile plant in Betim -MG, Brazil.
3.4 Calibration of the Car Radio

After generating test signals inside the chamber that are equivalent to the ones encountered in the field, the car radio was calibrated using the manufacturer's service manual. Soon after the calibration the test vehicle returned to the two original test sites for field evaluation of the calibration process. It was verified that the automatic seek operation performed well in both sites and that no undesirable tuning stops had occurred. Next, the car radio absolute signal-to-noise ratio during an automatic seek operation was measured using the RF generator and the result will be used to calibrate the radio in the production line.

4. Conclusion

Field measurement of FM broadcast signals in the 87.8MHz to 108MHz range can be reproduced inside a semi-anechoic chamber for the purpose of test and calibration of car radios. It is possible to establish the best signal-to-noise ratios for both near-field and far-field conditions. An average seek level can be found in order to optimize the radio operation in areas of strong and weak signals. The interface between the car radio and the driver can be also improved. The results show that it is possible to reproduce FM broadcast field signals inside a semi-anechoic chamber with good correlation results.

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6. References


