Co-location of different technologies in the same site

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Abstract- The aim of this paper is to promote the discussion and raise people’s awareness towards the creation of recommendations and regulations to improve the installation of different technologies in the same site. This research was accomplished with a theoretical approach and verified with real measurements of commercial Tower Mounted Amplifiers (TMA’s).

Index Terms- Blocking, co-location, harmful interference, tower mounted amplifier

I. INTRODUCTION

With the constant growing and sophistication of services portfolio, mobile operators have been developing investments in order to conjugate different technologies at the same infrastructure, thus facilitating the implementation of the network, the maintenance of the sites and reducing costs.

The sharing of the same site by different technologies or even different mobile operators brings many economic advantages, however, technically, the co-location of different radio technologies in the same location raises several questions that should be considered when the site is being implemented.

Several problems can appear in a congested site, such as intermodulation products, spurious emissions and receiver blocking.

Normally, equipment suppliers clearly accomplish the ETSI specifications [1][2] for the spurious emission requirements. Operators consider that the greatest problem when co-location exists, is the receiver blocking problem, because another transmission in the same site can interfere and block the desired signal reception.

The receiver block performance is defined by measuring the receiver’s ability to obtain a wanted signal on its assigned channel frequency in the presence of an unwanted interferer. This must be for all frequencies other than those of the adjacent channels. The unwanted input signal causes a degradation of the performance of the receiver beyond a specified limit. [1]

This paper has four different sections. The first one introduces the work. The second one is devoted to the theoretical background. The third one presents measurements of a UMTS commercial TMA, illustrating the real blocking effect. Finally, in the last section we present the main conclusions.

II. THEORETICAL BACKGROUND

A nonlinear system introduces several terms in the output of the system.

For instance, consider a third degree nonlinear system where the output can be represented by a 3rd degree polynomial:

\[ y(t) = a_0 + a_1 x(t) + a_2 x^2(t) + a_3 x^3(t) + \ldots \] (1)

Using two-tone signal in the input, the output of the 3rd degree polynomial is defined by:

\[ y_3(t) = a_3 x^3(t) = a_3 (A_1 \cos(\omega_1 t) + A_2 \cos(\omega_2 t))^3 \] (2)

\[ y_3(t) = \cos(\omega_1 t) \left( \frac{3}{4} a_2 A_1^3 + \frac{1}{2} a_3 A_1 A_2^2 + a_4 A_1 A_2 A_3 \right) + \]
\[ + \cos(\omega_2 t) \left( \frac{3}{4} a_3 A_2^3 + \frac{1}{2} a_3 A_1 A_2^2 + a_4 A_1 A_2 A_3 \right) + \]
\[ + \cos(3\omega_1 t) \left( \frac{1}{4} a_2 A_1^3 + \right) \]
\[ + \cos(3\omega_2 t) \left( \frac{1}{4} a_2 A_2^3 + \right) \]
\[ + \cos((2\omega_1 + \omega_2) t) \left( \frac{3}{4} a_2 A_1 A_2^2 \right) + \]
\[ + \cos((2\omega_2 + \omega_1) t) \left( \frac{3}{4} a_2 A_1 A_2^2 \right) + \]
\[ + \cos((2\omega_1 - \omega_2) t) \left( \frac{3}{4} a_2 A_1 A_2^2 \right) + \]
\[ + \cos((2\omega_2 - \omega_1) t) \left( \frac{3}{4} a_2 A_1 A_2^2 \right) \] (3)
As one can see in the first term of the equation (3), we have power of the spectral component at \( \omega_2 \) that fall on the frequency \( \omega_1 \). If the power of the \( \omega_2 \) component is stronger than \( \omega_1 \), the reception of the \( \omega_1 \) component can be damaged.

Thus, considering \( \omega_1 \) the wanted signal and \( \omega_2 \) the interferer signal, the term that is the cause of blocking effect is described by:

\[
IM = \left[ \frac{3}{2} a_3 A_1 A_2^2 \right] \quad (4)
\]

The power gain is given by \( |a_1|^2 \) and using the next expression [3] it is possible to obtain a relationship between \( a_3 \) and 3\(^{rd}\) order intersect point (IP3):

\[
IP3 = \frac{2 |a_1|^3}{3 |a_3|} \quad (5)
\]

Amplitudes can be transformed by power \( P = \frac{A^2}{2} \), resulting at (linear units):

\[
IM = \frac{G \sqrt{P}}{IP3} 2P_2 \sqrt{2P_1} \quad (6)
\]

Where \( P_1 \) is the minimum power that the receiver is able to receive, thus, \( P_1 \) is the sensitivity of the receiver and than it is represented by \( S_1 \).

The maximum value of IM allowed by the receiver represents the difference (quotient in linear units) between \( S_1 \) and the minimum SNR required by the receiver’s technology. \( P_2 \) is the interferer power coming from the other antenna that can actually reaches the receiver of the desired signal and it can be calculated, at a real scenario, by:

\[
P_2 = Pe + Ge(\alpha) + Gr(\alpha) - Lc - Lcr \quad (7)
\]

Where \( Pe \) represents the emission power of the interferer antenna and, \( Lc \) and \( Lcr \) represent respectively the power cable losses on the reception and the emission. \( Ge(\alpha) \) and \( Gr(\alpha) \) are the transmitting and receiving antenna gain in the direction \( \alpha \) of the other antenna, thus this value depends of the antennas position and it is obtained by the antennas’ patterns.

Finally, considering all previous expressions and using the free space loss \([4\pi d/\lambda]^2\] , the minimum distance \( d \) between two antennas separation is given, in linear units, by:

\[
d = \frac{\lambda}{4\pi} \sqrt{\frac{2G_2G_1^2/\lambda^2SS_1P_2}{IP3^2/SNR}} \quad (8)
\]

Where \( \lambda \) is the wavelength of the interferer antenna and \( P_2 \) is the radiated power by the interferer antenna that reaches the receiving antenna.

On the side of the antenna victim of interference we have a Low Noise Amplifier (LNA) with gain \( G \) and 3\(^{rd}\) order intersect point (IP3). The sensitivity of the receiver is given by \( S_1 \) and SNR is the minimum tolerable signal to noise ratio of the receiver technology.

Thus, it is possible to calculate the minimum distance between co-sitting antennas to avoid the blocking effect.

Error Vector Magnitude (EVM) and Signal to Noise Ratio (SNR) are measurements used to analyse the quality of transmissions. These measurements are related by [4]:

\[
EVM = \frac{1}{\sqrt{SNR}} \quad (9)
\]

III. TMA BLOCKING CASE STUDY

Then, to verify the practical blocking effect problem was tested a UMTS commercial TMA normally used for the mobile operators in Portugal.

Increasing the interferer signal for -40dBm to 10dBm and maintaining the wanted signal at -80dBm (it is the minimum detectable signal by the TMA, according to the mobile operators), measurements of the EVM and SNR were taken, in order to observe the degradation of the quality of the wanted signal, using different interferer technologies.
The quality of the desired signal remains constant, but, from a certain value of interferer signal, the EVM increases and SNR decreases.

The figure above refers the same technology that figure 2, nevertheless the degradation of the desired signal is stronger. This can be explained by the proximity of the frequency bands, so the TMA’s band-pass filter can’t reject the interferer power on the proximity of the passband like others frequency distants of the passband.

Considering figures 2 to 6, it is possible to observe that as long as EVM increases, SNR reduces. The effect of interferer WiMAX and WLAN are the largest, because the Peak to Average Power Ratio (PAPR) is higher on those technologies.
As shown in figure 7, the measured EVM and the theoretical EVM calculated by (9) are similar, resulting in almost coincident graphs and consequently proving the validity of this equation.

IV. CONCLUSION

When a strong signal interferes with a weak (desired) signal, the reception of this desired signal is damaged.

This degradation of the desired signal depends on technology that causes the interference. Technologies with high Peak to Average Power Ratio (PAPR) introduce higher blocking effect.

It was also proved that the blocking effect is a strong problem in the co-location solutions.

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