International Telecommunication Union

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Reference model to be used for the assessment of interference into the television broadcasting service in order to take into account non-linearity in the television radiofrequency receiving system

BT Series

Broadcasting service (television)

International Telecommunication Union

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Reference model to be used for the assessment of interference into the television broadcasting service in order to take into account non-linearity in the television radiofrequency receiving system

(2014)

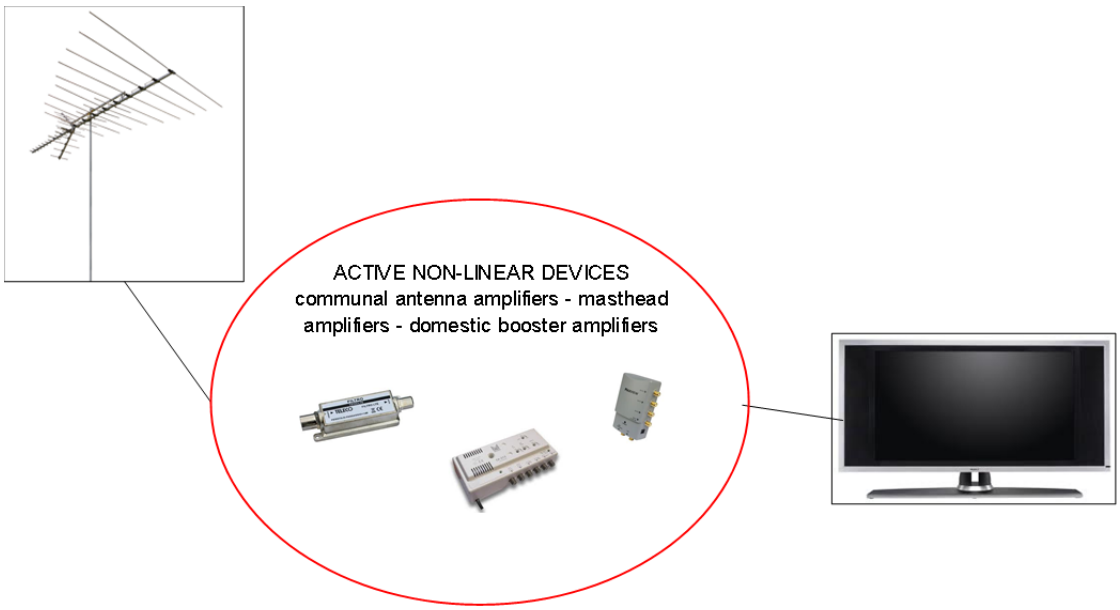
1 Introduction

When a multitude of signals multiplexed in the frequency domain is processed by a non-linear device, intermodulation products are present at the output of that device due to intermodulation among the input frequencies, potentially affecting all the distributed channels.

Characteristics of TV distribution amplifiers have to be carefully assessed during the installation phase, in order to minimize intermodulation distortions in normal operating conditions. However, if at a later time new high level signals (e.g. LTE signals) are received, intermodulation products can significantly increase if the setup parameters are not re-adjusted to the new environment signal levels. In the last case, the weakest television signals could be overwhelmed.

FIGURE 1

Distribution system



2 Model of a wideband distribution amplifier

The *I*/*O* characteristics of a non-linear amplifier can be modelled as its series expansion truncated at the 3rd order[1], as follows:

$$V_o = c_1 V_i + c_2 V_i^2 + c_3 V_i^3$$

[1] In case of very high input signal levels, a more precise approximation could be achieved with a 5th order model [1].

where:

V_i: input voltage

V_o: output voltage

c_1: amplifier gain

c_2, c_3: 2nd and 3rd order coefficients of the series expansion.

A wideband distribution amplifier can be characterized by means of its maximum gain, nominal output level and corresponding values of 2nd and 3rd order InterModulation Distortion (IMD).

Typically, the nominal output level is given according to DIN 45004B, i.e. as the value corresponding to a 3rd order IMD equal to –54 dB if measured according to the two-carrier method, or –60 dB if measured according to the three-carrier method [2].

By definition, this nominal output level is referred to two input signals: in a real environment, the output level of each TV channel should be therefore properly reduced according to the following formula [3], providing the correct amplifier regulation in a condition "before" the introduction of LTE signals:

$$\Delta P = 10 \log (n_c - 1)$$

where:

n_c: number of distributed channels.

Once the output level has been properly set (i.e. adjusting the amplifier gain), the *I*/*O* characteristics can be simplified as follows:

$$A_o = A_i - k_2 A_i^2 - k_3 A_i^3$$

where:

$$A = \sqrt{P} = \frac{V}{\sqrt{R}}, \text{ with } R = 75\ \Omega$$

the gain has been normalized to 1.

The coefficients k_2 and k_3 can be calculated on the basis of the 2nd and 3rd order IMD values [4], according to the following formulas:

$$k_2 = \frac{1}{\sqrt{2}} \cdot 10^{\frac{-(P_{\text{nom}} - IMD_2)}{20}}$$

$$k_3 = \frac{2}{3} \cdot 10^{\frac{-(2P_{\text{nom}} - IMD_3)}{20}}$$

where:

P_{nom}: nominal output level (dBm)

IMD_2: 2nd order IMD (dB)

IMD_3: 3rd order IMD (dB), measured according to the two-carrier method[2].

The described general model is valid for any wideband distribution amplifier.

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2 Equal to the 3rd order IMD measured according to the three-carrier method +6 dB.

Different classes of amplifiers, whose market penetration varies from country to country, can be installed in domestic installations [5], [6], differing in gain and nominal output level:

Communal antenna amplifiers

– These amplifiers are widely used in apartment blocks to allow DTT signals received from a single antenna to be boosted sufficiently for distribution to multiple dwellings within the apartment block. Typically these amplifiers are professionally installed to operate close to saturation. The nominal output power of such devices is typically (but not exhaustively) in the range 110-130 dB(μV), and the gain is typically in the range 20-50 dB (adjustable).

Masthead amplifiers

– These are small booster amplifiers fitted to the top of the antenna mast and powered by DC injected into the antenna cable, whose purpose is to serve a single house or a small number of apartments. The nominal output power is typically lower than communal antenna amplifiers, i.e. in the range 90-115 dB(μV), and the gain is typically in the range 15-30 dB, often adjustable.

Domestic booster amplifiers

– These devices can be installed in attics by the original house builders or by the final user within his apartment. The nominal output power is typically in the range 80-110 dB(μV), and the gain is typically in the range 5-20 dB, fixed or adjustable.

3 Simulation models

The 2nd order intermodulation products fall at frequencies like $f_1 \pm f_2$ or $2f_1$, while 3rd order intermodulation products fall at frequencies like $f_1 \pm f_2 \pm f_3$, $2f_1 \pm f_2$ or $3f_1$, where f_1, f_2 and f_3 are any of the carriers belonging to the input signals (DVB-T or LTE)[3].

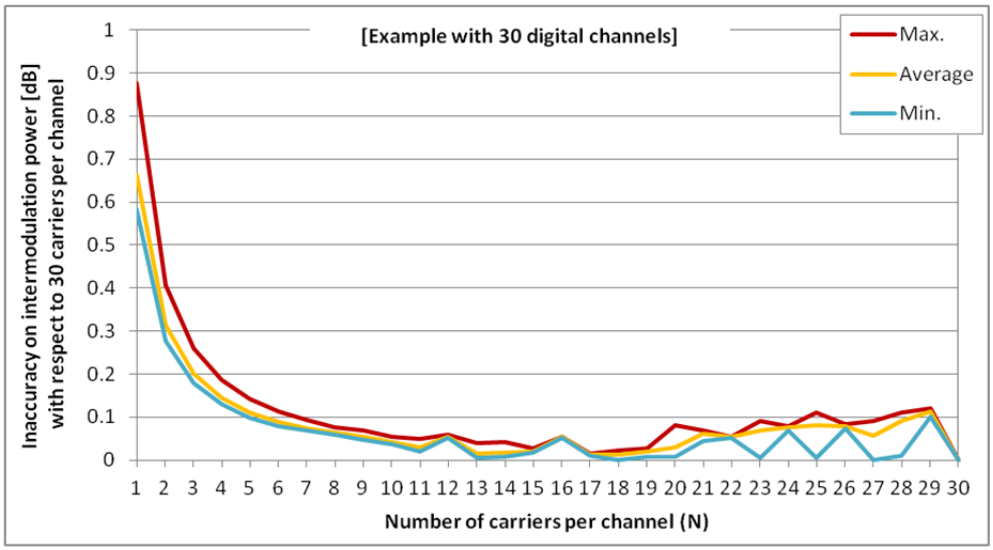
Each of the DVB-T and LTE OFDM signals can be modelled as a number N of equally spaced carriers, distributed within the relevant bandwidth (i.e. 8 MHz for DVB-T channels, 5 or 10 MHz for LTE channels), having a power equal to $1/N$ of the signal power. The number N has to be chosen as a trade-off between accuracy and simulation time.

As an example, Fig. 2 shows the inaccuracy of the calculated intermodulation power as a function of the number N of carriers per channel, determined in a specific case relevant to 30 channels and average intermodulation power equal to –38 dBm.

[3] Considering devices operating in the UHF TV band (i.e. 470-862 MHz), only 3rd order beats at frequencies like $f_1 \pm f_2 \pm f_3$ or $2f_1 - f_2$ can contribute to intermodulation products in the TV signals bandwidth.

FIGURE 2

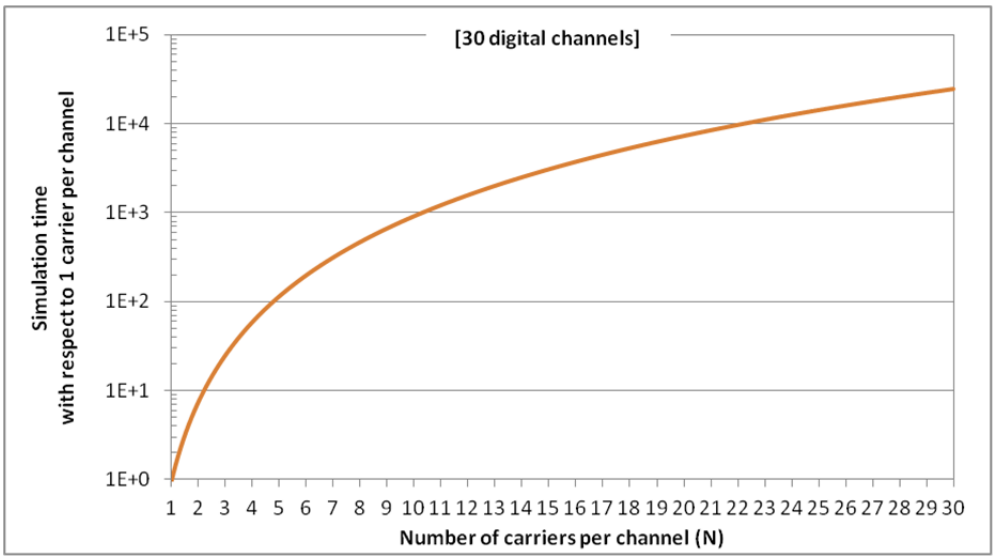
Inaccuracy of the calculated intermodulation power as a function of the number of carriers per channel



The simulation time increases with the total number of carriers, i.e. the number of distributed channels n_c multiplied by the number N of carriers per channel. Figure 3 shows the estimated simulation time as a function of the number N of carriers per channel, in the case of 30 channels, with respect to the simulation time in case of one carrier per channel (set equal to 1).

FIGURE 3

Estimated simulation time as a function of the number of carriers per channel (with respect to one carrier per channel, 30 channels)



Also the thermal noise generated inside the in-building distribution system should be included in the simulations. It can be determined on the basis of the typical noise figure of a DVB-T receiver (i.e. 7 dB [7]), applying a further margin to include the active and passive components of the MATV network (i.e. 4 dB [3]).

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