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A Report On Technical Issues Relating to Mobile Communications

Brief Overview of the Intermodulation Interference Reduction Techniques

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1. Introduction

Radio transmitters are becoming ever more prevelant. Towers carry a variety of radio services across a broad spectrum of frequencies. Attention must be given to intermodulation distortion caused by the combination of many of these frequencies. During the initial design phase it is wise to consider all the possible causes of intermodulation interference and to rule out rare possibilities and take necessary precautions against legitimate possibilities. In this and subsequent editions of our newsletter we'll attempt to clarify the issues, provide guidance in practical cases, and assess the usefulness of computer tools in the analysis.

In addition we will review the FCC specifications for undesired harmonics and spurious emissions for transmitters in each radio service.

2. Practical considerations

Intermodulation Interference reduction methods primarily attempt to reduce the coupling between transmitters. They include:

- transmitter shielding
- proper antenna installation
- adequate antenna spacing (vertical & horizontal for a given distance, vertical separation achieves greater coupling loss than a horizontal separation)
- proper grounding system (especially for the transmitter, the larger the diameter of the copper conductor to the ground the better)
- matching of the antenna systems with the transmitter (low standing wave ratio; RF frequencies are radiated easily, that is, loose connection on coax cables;poor joints; this usually results in a poor SWR. as well)
- filtering at the transmitter and receiver (filtering at the transmitter to reduce the intermod output and at the receiver to reduce the reception of the undesired frequencies that may cause intermod distortion in the receiver; filters are placed between the antenna system and the transmitter / receiver)
- power line filtering, in case the power feeds have induced interference; in this case the interfering frequencies must be known.
- use of isolators, circulators, and harmonic filters (isolators are devices that allow signal transmission in one direction with negligible loss, but introduce high loss for signals in the opposite direction of transmission; the isolators are placed between the antenna system and the transmitter)
- combiners, multicouplers, duplexers have inherent

isolation by their very nature.

3. Brief theory and background

Intermodulation distortion is the result of the nonlinear combination of multiple frequencies. Nonlinearities are used intentionally in many applications such as square law modulators, compandors, and limiters. Active devices such as oscillators, mixers and multipliers are additional examples of intentional non linearites. However when linear performance is desired such as in amplifiers, presence of even weak nonlinearites can limit the use of the amplifiers. Nonlinearities commonly occur at the input of elements such as diodes, transistors, final stage of amplifier circuits and coils and transformers using ferrous materials. When two transmitter signals are coupled by a transmission path such as antenna system or poor ground system, intermod products are likely to occur and be transmitted by the antenna system.

Intermodulation products are:

- Second order products are Second harmonics and sum and difference frequencies; if A is the fundamental frequency, then 2*A is the second harmonic; the sum and difference frequencies are A-B and A+B. It can be shown that if the magnitudes of the multiple frequency inputs are the same, then the power of the sum and difference frequency products are 6dB greater than the second harmonic. Since in most cases the sum and difference products lie outside the bandwidht of interest, these products are usually not considered. However one should be aware of their existance and analyzed on a case by case basis.

- third order products consist of third harmonics and 2*A-B, 2*A+B, A+B+C, A+B-C, A-B+C, and A-B-C cominations; if the magnitudes of the multiple frequencies are equal then the 2*A-/+B magnitude is 9.6dB greater than the third harmonic product; the A+/-B +/- C magnitude is 15.6 dB greater than the third harmonic.

Intermodulation Products

IM Form	Order	# of Freq. involved	Total # of IM products
2*A-B	3	2	N*(N-1)
A+B-C	3	3	N*(N-1)*(N-2)/2
3*A-B-C	5	3	N*(N-1)*(N-2)/2
A+2*B-2*C	5	3	N*(N-1)*(N-2)
A+B+C-D-E	5	5	N*(N-1)*(N-2)*(N-3)*(N-4)/2

From the above discussions it can be seen that the harmonic frequencies are not necessarily the most troublesome. Similar analysis can be done for fourth and fifth order intermod products. It can be shown that the most troublesome intermod products are odd order products. The table below shows the number of intermod products of each order and form. For example for ten transmit and ten receive frequencies, there are 90 intermod products of the form 2*A-B and 900 comarisions, 360 intermod products of the form A+B-C and 3600 comaprision and so on, A computer program is essential if any sizeable number if frequencies are involved.

4. Computer Program

An intermodulation product enumeration program that runs on an IBM PC has been written to assist in the analysis of intermodulation distortion and interference. The program requires as input all transmitter frequencies and all receiver frequencies for which intermod

interference is to be considered. The program computes all intermod products and determines if any resulting intermod is within a given window of any receive frequencies. Documentation provided with the computer program, guides the user through a step by step analysis of the output of the computer program based on his / her real situation.

A copy of this computer program or on the floppy disk, including the associated documentation, may be obtained. Contact GL Communications for more details.