Electromagnetic compatibility of cosite radio installations

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Abstract. Paper discuses some issues of electromagnetic compatibility in situation when more radio communication sources are placed inside a communication shelter. Review and discussion of the many collocation challenges that affect the performance of radio communications are presented. Various mechanisms of collocation interference generation from transmitter and receiver point of view are discussed.

Keywords: Multiple radio installation, electromagnetic compatibility of cosite installation, interference free operation of multiple radios at one installation.

1 Introduction

On present battle field with asymmetric warfare progressing requirement of high mobility of forces is the most important. In such environment only way how to keep and increase the information exchange on critical mission areas is to use wireless communication.

To achieve radio communication support for different capabilities more radio transmitters and receivers are installed and operate within the same site. Main advantages of a single site installation for radios and antennas are easy maintenance, logistic support and concentration of communication channels in one communication node, are in contrast with the need to separate antennas and radios connected to them to minimize collocation interferences.

Often, especially in multiple HF ground radio installations, system designers must resort to build geographically separated transmitter and receiver sites to eliminate radio collocation problems. Fortunately for VHF/UHF radios is solution for collocation simpler due to shorter wavelength.

A review and discussion of collocation interference challenges are presented in the paper.

2 Electromagnetic compatibility

Overall electromagnetic compatibility is determinated by:

- frequency coexistence;

- amplitude coexistence;
- time coexistence.

Electromagnetic fields will be compatible if one of partial coexistences will be achieved when antennas are separated enough. On single-site installation frequency coexistence and amplitude or time coexistence have to be achieved at the same time to ensure that radio receiver performance is not decreased.

Mutual interferences inside of a radio communication system might be created as results of undesired transmitter radiation on the transmitter side (Fig. 1) and as results of a receive of undesired interference signals on basic or spurious receiving channels on receiver side (Fig. 2). System noise is produced due to absence of technically perfect circuits which are able to eliminate spurious transmission.

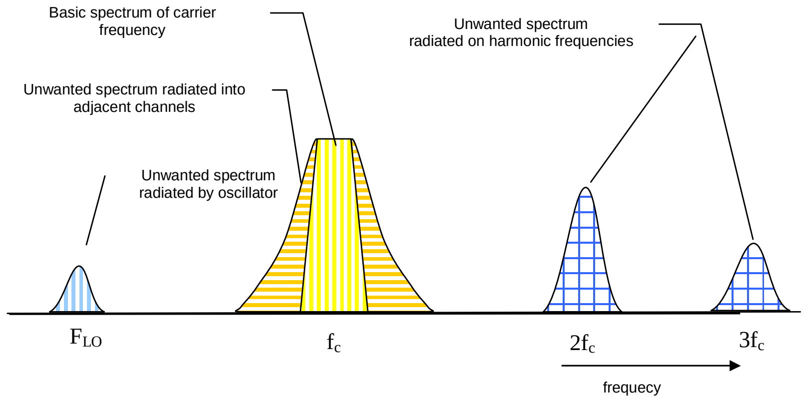

Fig. 1. Desired and undesired spectrum radiated by transmitter

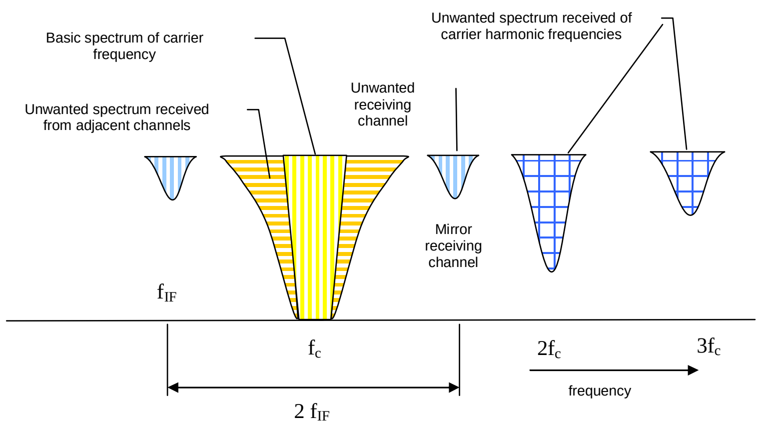

Fig. 2. Possible receiving channels of receiver

2.1 Frequency coexistence

The following procedure can be used for electromagnetic coexistence evaluation of assigned frequencies with accent on above mentioned sources of mutual interferences. For any pair of frequencies F_i, F_j from the set of operational frequencies F the following relations have to be satisfied:

$$F_i \neq \left| \pm nF_i \pm mF_j \right|, \tag{1}$$

$$F_j \neq \left| \pm nF_i \pm mF_j \right|, \tag{2}$$

$$\Delta f \geq \left| \left| \pm nF_i \pm mF_j \right| - F_i \right|, \tag{3}$$

where n, m are positive integers (0, 1, 2, 3, …), Δf is minimum allowed frequency separation of frequencies F_i, F_j.
Addition of numbers m, n defines degree of harmonics

$$R_h = n + m\,. \tag{4}$$

If these relations are satisfied, we can say that frequencies F_i, F_j match conditions for electromagnetic compatibility.
Degree of harmonics R_h and minimum allowed frequency spacing Δf between frequencies F_i, F_j determine level of electromagnetic coexistence in frequency domain. In practical application, level of electromagnetic coexistence is chosen according antenna placement and technical parameters of radio technology in use.
If multiple radios are placed inside one platform, spurious sources of interference from transmitter and receiver are checked up to degree 5 or 7.
For solution of the problem, a graphical method with using of mixing product diagram was chosen. Diagram represents net of points (intersections of net) where each point represents some product of mixing.
To analyze mutual interference of two frequencies first of all we calculate ratio F_i /F_j and draw it into diagram. If the line crosses any of points, these frequencies do not fulfill frequency coexistence (Fig.3).

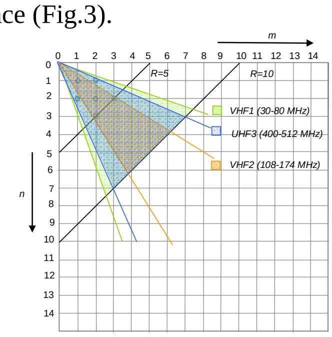

Fig. 3. Diagram of mixing products for subbands VHF1, VHF2 a UHF

2.2 Amplitude coexistence

Usually when amplitude coexistence is solved in situation when desired and undesired source of electromagnetic fields are far away from receiver we need to calculate field strength at the receiver antenna [2] only at operational frequency and to check if desired signal to undesired signal plus noise is big enough to receive the desired signal. If it is so than electromagnetic fields are compatible. Transmitter broadband noise and transmit spurious signals from transmitter of undesired signal are not strong enough to case interference at receiver at long distance because they are suppressed in transmitter and receiver filters are usually more than 60 dB under signal on operational frequency.

Situation is different when transmitter of undesired signal is quite close to the receiver. Transmitter broadband noise and transmit spurious signals also produce undesired signals at collocated receiver. These interfering signals are on nearly the same level or higher that the desired signal from distant transmitter. Such interference will occur usually only when the desired signal is very weak (around receiver sensitivity level) so during interference free operation test with the strong desired signal no interference occurs.

In such situation only way how to reduce and keep spurious transmitter spurious signal under appropriate level is to separate antennas in distance. Antenna isolation factor which depends on the distance and frequency is a free space loss value plus insertion loss on cabling minus transmitter and receiver antennas gains. It can be calculated by following formula

$$AI\,[dB]=20*\log(f\,[MHz]*d[m])-31{,}8-G_R[dBi]-G_T[dBi]+A_C[dB], \quad (5)$$

where AI is antenna isolation, f is frequency, d is distance between antennas, G_R and G_T are gains of transmitter and receiver antenna and A_C is insertion loss on cabling. Antenna isolation for various distances of antennas in frequency band 30 – 512 MHz is shown Fig.4 (antenna gains 0 dBi and without insetion loss on cabling). As can be seen from Fig.4 than to achieve antenna isolation 30 – 40 dB antennas have to be separated at quite big distance especially for frequencies 30 – 120 MHz.

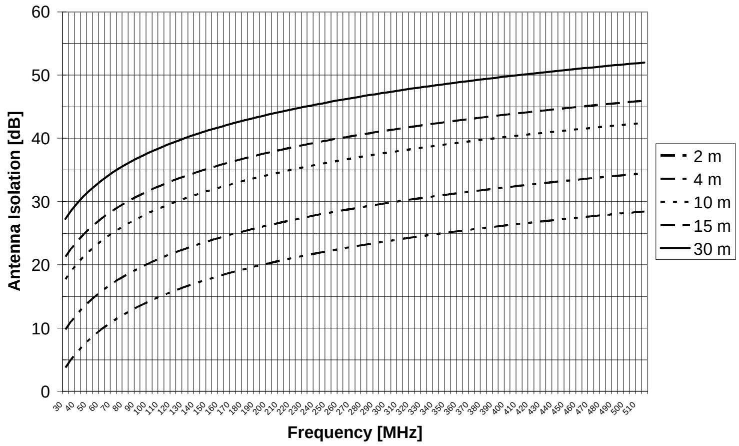

Fig. 4. Antenna isolation for frequency band 30 - 512 MHz

If dipole antennas are placed one above another on a mast, antenna isolation is theoretically infinite because dipole antennas do not radiate in their axis. Practical values of antenna isolation in such case are from 30 to 40 dB. This solution is very suitable for situations when such value of antenna isolation can be achieved only by long distance between antennas.

The main sources of interference from collocated transmitter are:

- transmitter broadband noise,
- transmitter reverse intermodulation distortion products,
- transmitter spurious outputs.

Transmitter broadband noise.

All transmitters emits small amount of broadband noise [1] along with the desired signal. If antennas of collocated transmitter and receiver are not isolated enough small amount of broadband noise can overwhelm weak signals being received by nearby receiver. Since broadband noise is always present at the weak desired signal frequency, nothing can be done at the receiver to prevent it. Manufacturer of radios usually disclose data about transmitter broadband noise in technical description of radio. It is measured in dBc/Hz (decibels relative to the carrier) for various frequency separations from carrier frequency and it is usually in range from -100 dBc/Hz to -175 dBc/Hz. To ensure interference free operation the antenna isolation should be big enough to make transmitter broadband noise equal or lower then receiver internal noise. Required antenna isolation can be calculated according following formula

$$RAI[dB] = BBN[dBc/Hz] + RDB[dB - Hz] - RNF[dBm/Hz], \qquad (6)$$

where RAI is required antenna isolation, BBN is transmitter broadband noise, RDB is receiver detection bandwidth and RNF is receiver noise floor. From required antenna isolation a minimal distance between antennas can be calculated.

Transmitter reverse intermodulation distortion products

Transmitter intermodulation distortion products (IDP) can occur at the output of transmitter [3] so collocated receiver antenna will pick up them. The IDP can be effectively reduced at tramsmitter by using narrow output filters (usually more then 40 dB bellow carrier level for 3^{rd} order products). If we assume that antenna isolation is about 40 dB and transmitter power of undesired signal is 10 W (40 dBm), than 3^{rd} order products at the nearby receiver will be about -40 dBm. This signal can easily overwhelm weak signals being received by nearby receiver. Therefore this kind of interference can be avoid only by proper frequency management as described in part 2.1 or can be eliminated by higher antenna isolation.

Transmitter spurious outputs

The signal from any transmitter will contain low-level undesired signals. Level of these spurious signals can be reduced by a clean transmitter synthesizer design and by bandpass filtering. Antenna isolation must make up remainder of the attenuation needed to keep these spurious signals from interfering with receiver. Usually recent radios produce no spurious signal above -80 dBc. In the worst case with antenna isolation about 40 dB and with carrier power is 10 W (40 dBm) signal at the nearby receiver will be about -80 dBm and bellow.

2.2 Time coexistence

In case when amplitude coexistence on single site installation can not be achieved (required antenna isolation can not be achieved) only way how to avoid interferences especially when receiving weak signals (long distance communication) is to disable transmission on another radio while receiving desired signal.

3 Conclution

Aim of the paper was to focus attention on fact that solving of electromagnetic compatibility of cosite multiple radio installation is different from situation with distant radios. In process of radio communication system design problem of electromagnetic compatibility is very often addressed after prototyping. Results from analyze of electromagnetic compatibility then introduce a lot of changes in antenna placement and often a total redesign is required. Addressing problem of electromagnetic compatibility in early phases of project can save a lot of time and money.

References

1. Demir, A.; Mehrotra, A.; Roychowdhury, J. (May 2000), "Phase noise in oscillators: a unifying theory and numerical methods for characterization", IEEE Trans. on Circuits and Systems I: Fundamental Theory and Applications 47 (5): 655–674.
2. Rec. ITU-R P.1546: “Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz”.
3. Pedro,J.C., Carvalho, N.B. : Intermodulation Distortion in Microwave and Wireless Circuits, Artech House, 2003.