COMPUTING INTER MODULATION FREQUENCIES AND ANALYSIS OF MULTI RADIO SET INTERFERENCES

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Abstract

When more than one radio set is operating simultaneously in the same platform, the inter modulation frequencies are generated due to sum and difference frequencies of their carriers which could affect these radio sets mutually. Also these sum and difference interfering frequencies will have sufficient radiated field intensity especially the third order mixing products that could lead to blocking of signals in the receivers co located in nearby platforms also. Therefore it is necessary to evolve a frequency table for the entire operating band of frequencies of Radio sets, especially when it is more than two carriers. For three Radio sets mutual EMI problem this computation was carried out for a tactical vehicle equipped with HF, VHF-VHF Communication configuration. Besides inter modulation EMI in radio sets, there are EMI issues connected with Communication system installation aspects including grounding and other EMI contributions from co located electronic subsystems of same vehicular platform. This paper addresses those issues in brief and concludes with a consolidated flow chart for resolving them, illustrating the actions necessary for meeting the EMC goals of multi radio set Communication System.

Keywords: EMI, EMC, Inter modulation, Multi Radio sets, Harmonics, MIL-Std.

I. INTRODUCTION

In ground based military tactical vehicles, there are number of operational roles calling for using multi radio sets in the frequency region of HF,VHF and UHF with varying RF power levels and receiver sensitivities. Also the modes of operations could be either fixed frequency or frequency hopping type. Therefore a need arises to compute the inter modulation frequencies which act as interference to Communication systems mainly because of too many carriers involved and their close proximity of radiation effects on receivers/transmitters. The roles of vehicles decide the number of radio sets and, RF power levels decide the range requirements to be met in the installations. Unless due care is not taken both in installation and in system design, there is bound to be severe mutual EMI problems both within the vehicle as well as from vehicle to external links and vice versa. Some of the typical operational roles of tactical vehicles involving multi radio sets are:

(a) Command and Control role of Armoured Fighting Vehicles

(b) Carrier Command Post in Artillery Vehicles.

(c) Infantry Command Post Vehicles

(d) Surveillance Vehicles

(e) Intelligence gathering Mission Vehicles

In the present study reported in this paper, a modern Command post vehicle uses one HF and two VHF radio sets of 100 and 50watts of RF power respectively. Both computing of inter modulation frequencies and overall EMC measures carried out are discussed in brief.

II. INTER MODULATION INTERFERENCE AND ITS EFFECTS ON COMMUNICATION SYSTEM

Inter modulation interference is the undesired combining of several signals in a nonlinear device, producing new, unwanted frequencies, which can cause interference in adjacent receivers located at repeater sites. Not all interference is a result of inter modulation distortion. It can come from co-channel interference, atmospheric conditions. Most inter modulation occurs in a transmitter's nonlinear power amplifier (PA). The next most common mixing point is in the front end of a receiver.

Inter modulation is rarely desirable in radio or audio processing, as it essentially creates spurious emissions which can create minor to severe interference to other operations on the signal. Inter modulation should not be confused with general harmonic distortion (which *does* have widespread use in audio effects processing). Inter modulation specifically creates non-harmonic tones ("offkey" notes, in the audio case) due to unwanted mixing of closely spaced frequencies. RF Interference analysis modes are:

- Transmitter IM
- Receiver IM
- Transmitter Noise
- Receiver desensitization
- Transmitter Harmonics
- Transmitter Spurious Output

It should be noted that IM occurs in three distinctly different places within a radio system:

(a) In the Antenna.

(b) Transmitter IM.

(c) Receiver IM

Antenna IM is generated in the antenna (when two or more transmitters are combined into it). Transmitter and Receiver IM are usually due to interaction between systems attached to different antennas.

III. COMPUTATION OF IM FREQUENCIES FOR THREE RADIO SET CONFIGURATION

The general equation for the inter modulation product is written: I.M. $= n_1 A \pm n_2 B \pm n_3 C \ldots$ Where A, B, C, etc. are the mixing frequencies and n_1, n_2, n_3, etc. are the harmonics, or multiples, of the mixing frequencies. The order of the inter modulation product is equal to the sum of the harmonics (n_1, n_2, n_3, etc.). For instance, $A + 2B + 2C$ generates a 5^{th} order inter modulation term $(1 + 2 + 2)$. Additional examples of product order: the frequency obtained by adding or subtracting the fundamental frequencies A and B, that is, $A + B$ or $A - B$, are even 2^{nd} order products; likewise, $2A - B$ and $A + B - C$ are odd 3^{rd} order products while $3A - 2B$ is a odd 5^{th} order product while, $A + B + C + D - E - F - G$ generates a odd 7^{th} order inter modulation term $(1 + 1 + 1 + 1 + 1 + 1 + 1)$. There is no limit to the number of products, but only a few are of any practical concern. Even order products (2^{nd}, 4^{th}, 6^{th}, etc.) can generally, but not always, be dismissed since they usually fall outside the frequency "band" of interest.

When the number of transmitters is increased, the number of possible inters modulation frequencies increases rapidly. The most serious of these frequencies are the third order products of the form $2f_1 - f_2$ or $f_1 + f_2 - f_3$, where f_1, f_2 and f_3 are operating frequencies of the transmitters. The interference will be most serious when all or several of the frequencies, both transmitting and receiving, are in close proximity. To minimize inter modulation; frequencies should be selected such that the frequency difference between any pair of frequencies is unlike the difference between any other pair. In some cases, the specific operating frequencies can be chosen so that no third order product frequency coincides with a receiving channel frequency at the same or a nearby site.

3.1 Harmonic Analysis Equation;

The mixing of frequencies whereby the largest frequency is greater than twice the smallest frequency is not analyzed. Harmonic interference is defined below;.

$$A\, f_t = f_r \pm BW \quad (1)$$

where, A is either 1 or 2, f_t is the transmitter frequency, f_r is the receiver frequency and BW is the receiver bandwidth.

3.2 Inter modulation Analysis;

The interference due to inter modulation is defined by the following equations. The analysis only considers in-band modulation products.

3.2 (a) Two Signal Case

3rd order: $2\, f_{t1} - f_{t2} = f_r \pm BW$, (2)

5th order: $3\, f_{t1} - 2\, f_{t2} = f_r \pm BW$ (3)

7th order: $4\, f_{t1} - 3\, f_{t2} = f_r \pm BW$ (4)

3.2 (b) Three Signal Case

3^{rd} order: $f_{t1} - f_{t2} + f_{t3} = f_r \pm BW$ (5)

5^{th} order: $2\, f_{t1} - 2f_{t2} + f_{t3} = f_r \pm BW$ (6)

$3\, f_{t1} - f_{t2} - f_{t3} = f_r \pm BW$ (7)

7[th] order: $2f_{t1} - 3\,f_{t2} + 2f_{t3} = f_r \pm BW$ (8)

$3\,f_{t1} - 3\,f_{t2} + f_{t3} = f_r \pm BW$ (9)

$4\,f_{t1} - 2\,f_{t2} - f_{t3} = f_r \pm BW$ (10)

3.3 Inter modulation Interference reduction methods:

This is primarily attempted 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 inter mod 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.

IV ANALYSIS OF MULTI RADIO SET INTERFERENCES

Apart from the Inter modulation frequency predictions and making sof sub tware solution for the three Radio sets, there is a need to look into other interfering aspects of the Communication System for a consolidated solution. This is explained in the form of a Comprehensive Flow Chart as shown in Figure.1 This chart can be briefly divided into five parts as listed below;

A. Field mapping survey to locate Radio sets.

B. Computing of Inter modulation frequencies between three Radio sets.

C. Installation aspects with respect to performance.

D. Power Quality and

E. Other EMI sources in the Vehicle and their EMI control.

Now each part will be explained to get an overall idea about the total EMC solution achieved. The first part deals with optimally locating the HF transmitter Receiver (Because this is introduced for the first time with 100 watts of RF power and receiver sensitivity level of - 107 dBm). RF field mapping roughly indicates the magnitude of field intensity prevalent in various locations of the vehicle, so that from the contours of RF field intensity in the frequency range of 1 to 88MHz, sensitive receptors both on board vehicle and inside the vehicle could be located in such a way that they are not affected or least affected by the electromagnetic field.

The second part deals with the Computation of inter modulation frequencies as already explained in paragraphs 1 to 3 above. This computation is repeated for two VHF radio sets working in 30-88MHz , one HF set working in 1-30MHz and one each VHF set, and finally all the three sets working together. The user inputs selected frequencies either two sets combinations or three set combinations and get the selected frequencies approved if the inter modulation frequency is not likely to interfere with any of the frequencies selected. In case of rejection, the user has to try another frequency by selection till such time inter modulation interference free frequency is obtained. While software is rejecting the IM frequencies, RF coaxial low pass[HF] and band pass filters [VHF] reject the harmonics and out of band interfering frequencies. Use of Proper RF Coaxial cable for the radio sets to filters and filters to antenna are important as filter pass band loss and coaxial cable loss put together can reduce the effective power radiated from the transmitter as well as reduce the signal received from antenna during reception, leading to reduction in Communication Range.

The third part deals with important aspects of all installation related checks. Out of these, the antenna mounting and its grounding are very important checks as these could distort the radiated pattern as well as produce severe reflections and consequent mismatches. Similarly the reduced inter distance between the antennas, metallic obstructions in the vicinity of antenna mounting etc can cause similar problems which ultimately matters in the overall EMC of Communication System and range obtained in real situations. Next important check is the measurement of VSWR in the vehicle with individual radio operated from start to end frequency of each radio set. Here we will come to know which the frequencies not favourable for communication are. Next very important check is the plotting of radiation pattern of each antenna which will confirm the correctness of the antenna mounting. These checks enable the system engineer to make corrective actions during the installation.

Power Quality is always playing an important role in the system availability. As Combat Tanks operate with many small and large current devices, it is very critical and no serious dip in bus voltage is permitted in modern radio sets. They have to comply with MIL-STD1275B Power quality specifications. But unfortunately most of the radio sets do not comply with this requirement and hence calls for supplementing with a back up battery of appropriate AH rating to sustain the bus voltage, so that radio sets do not trip during severe operations either with tank engine starting or with turret traversing.

The last part of the check deals with overall EMC aspect of the vehicle where individual care of Communication System, sensitive critical electronic systems and their operational availability and performance are checked independently and together while functioning. After ensuring the overall EMC, Communication system functional availability is further enhanced, by avoiding lightning strikes to their antennas by incorporating a suitable lightning arrestor in the antenna circuit. This is a gas arrester which operates on the principles of dielectric breakdown during lightning charging process thereby opening the RF circuit, passing lightening current to the skin of the vehicle and protecting the Communication system and crew of the vehicle. As soon as the lightning ceases, the RF path is active and communication channel is restored. Thus the overall functioning of all electronics subsystems and communication system are ensured with proper EMI control to achieve the desirable level of EMC.

V. CONCLUSIONS

We have addressed a methodology to compute Inter modulation frequencies of pairs of two radio sets and three radio sets with HF and VHF combinations ,which is the current usage trend in the modern combat vehicles for Command Communications and how to avoid interference due to those frequencies both by employing software for User's Frequency Management as well as by introducing hardware modifications to Communication System. Special emphasis on multi radio set interference analysis is briefly explained in the context of Communication System EMC problems normally encountered in Combat Vehicles, by breaking the problem into various contributing elements and separately treating them and making a final check when subsystems are integrated for the overall EMC of the vehicle with emphasis on Communication System. Effectively there are fifteen decision making logics in the flow chart referred in the Figure-1,which accounts for the complete procedure evolved for overall system checking methodology to ensure that the solution is implemented effectively and this is the key issue of study carried out. This methodology establishes an EMI free operation of Communication system in a Command Vehicle for fixed frequency narrow band operations, thereby increasing the operational availability that is very important technically and strategically in any war theatre.

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