SELECTION OF OPTIMUM LOCATION FOR THE HIGH POWER HF TRANSMITTER-RECEIVER IN A DENSE COMBAT VEHICLE EMI ENVIRONMENT

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Abstract

This paper discusses the procedure adapted after carrying out several iterations for selecting the ideal location to introduce a high power HF Transmitter-Receiver in a tactical Combat Vehicle from the Electromagnetic Compatibility point of view. This radio set is generally contributing for very high field strength to neighbouring electronic devices so also to other two VHF Tx-Rx situated in the same vehicular platform. A two pronged approach was followed in deciding the optimum solution to locate the HF Radio set. Emission levels from HF radio set is to be minimised within the vehicle when crew hatches are closed(normal operating condition of the vehicle)to reduce coupling level to neighbouring equipment. Emission from HF antenna was maximised insitu by careful installation of antenna, outside the vehicle environment to ensure optimum radiation of intended signal. Four different configurations experimented are reported in this paper. HF being a congested operating spectrum ,due care was taken in EMI control of HF-VHF radios and other electronic subsystems to have minimal amplitude varying [AM] interfering signals and also to minimise inter modulation EMI effects [IMI]from two VHF- FM radios, thereby ensuring the selection of optimum location.

Keywords: VPL, HF, VHF, AM Modulation, FM, Spectral Congestion, EMI, EMC , IM , VSWR etc.

I. INTRODUCTION

Hitherto tracked Combat Vehicles in armoured fleet were using only a 50 watts of RF power, HF radio set for long distance ground communication link. Of late, with the development of solid state frequency hopping radios, high power radios have come into use particularly for enhanced voice communication range requirement and also for data transmission capability. These requirements have compelled the radio set designers to think of high power HF Radio sets, but this leads to several EMI issues, .if due care is not taken during system integration in the vehicular platform. Typical range (Ref1) achievable with various RF power levels in a HF Radio set is depicted in Fig1..This is basically derived from the basic thumb rule equation given by (Ref2).

$$R \approx \sqrt[3]{P} \qquad \text{<<.} \quad (1)$$

where R is the range in km and P is the effective RF power radiated in watts.

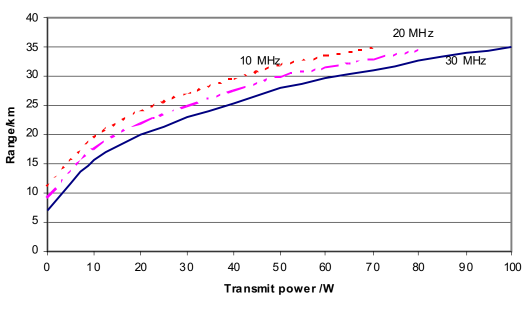


Fig. 1. Range of radio signal as a function of transmit power with frequency as parameter

An increase in transmit power extends the range only insignificantly. To achieve double the range one has to increase the transmit power by eight times. For the present case of 100watts at least 35 km range is expected at highest frequency of 30MHz. But at lower frequencies the maximum range of 50 km can be expected. Whenever there is reduction in range it could be due to severe propagation loss/fading or due to interfering signals or both.

As far as data transmission is concerned, range achievable largely depends on the bandwidth of channel as is evident from Fig2 **(Ref1)** shown below. The required bandwidth is proportional to the data rate.

$$\text{rate. } R \quad \frac{1}{\sqrt[C]{\beta_{HF}}} \qquad (2)$$

where R= is the range in km, Bhf is the required bandwidth in KHz or requested data rate. However the range decreases with increase in band width. Keeping these two user requirements as prime objective, EMC solution of this new product was attempted.

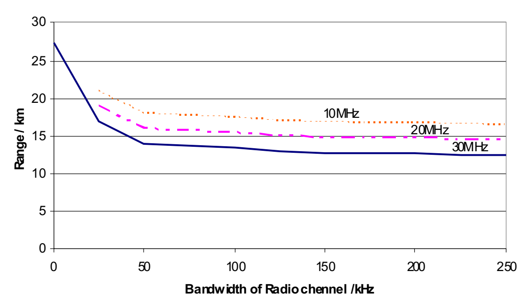


Fig. 2. Range as a function of the bandwidth of radio channel

II. EMI ENVIRONMENT

EMI environment of this particular vehicle is somewhat complicated due to introduction of three radio sets in a tactical Combat Vehicle , out of which the HF Radio set is the potential emitter of 100 watts of RF power in the frequency region of 1.6 to 30 MHz [AM] while the other two radio sets operate in the VHF frequency region 30 to 88 MHz [FM]with an RF power output of transmitters 50 watts each.. Apart from these two VHF Radios, there are at least four powerful electronic subsystems which had potential EMI emission spectrum in both HF and VHF spectrum but they were tackled efficiently with EMI hardening independently and collectively [particularly in power line EMI filtering] and hence will not be discussed in detail further. EMC of Communication System calls for extensive analysis with respect to transmitters, receivers antennas and associated interconnections.(**Ref2**)

A term vehicle penetration loss VPL or the normal shielding effectiveness **(Ref3**) of armoured skin of vehicular platform is very important parameter in our case which is expressed in decibels, is defined as the ratio of received power Pout immediately outside the vehicle to the received power Pin inside the vehicle.

$$VPL = 10\log\frac{p_{out}}{p_{in}} \quad \text{<<.} \quad (3)$$

Unless the entire vehicle EM wave penetration points such as service outlets, exhaust, antenna mount seal, grills in engine compartment, weapon system mounting interfaces etc are treated fully for EMI seal, even closing of crew hatches can lead to only 0 dB of VPL in spite of large thickness of usual armour skin.. However such treatment will reduce the direct field coupling from HF antenna to inside electronic equipment, which is most desirable and hence lowest EMI ambient inside the vehicle not only the carrier level so also to its harmonic levels **(Ref 4).** It may be a worthy exercise to carry out a separate study to minimise the vehicle EM ambient by performing such treatments to various vulnerable points of EM wave penetration in large structure like a Combat vehicle turret and hull. In the present study, the ambient due to four non communication electronic subsystems and all three radio sets of the Communication system are considered.

III. CRITERIA FOR SELECTION OF OPTIMUM LOCATION

Selecting the optimum location for the HF Radio set and its accessories are basically driven by the following technical requirements;

(a) Least susceptible to EM ambient in its receive mode and also least EM leakages, when the transmitter is radiating its full RF power for its intended communication .That is total EMC.

(b) All its control knobs, displays, settings are easily accessible to crew.

(c) Minimum distance prescribed by manufacturer of radio set is maintained between antenna and its coupler.

(d) Minimum simple hardware is required to install the system with due care for effective grounding, achieve protection against vehicle vibrations and make effective interface to power supply, RF, Control and associated connections.

(e) Maximum physical isolation of HF antenna to rest of coupling devices, as power involved very high.

Once the optimum location is identified based on the above parameters, then the complete HF radio set and its accessories like antenna coupler, RF feed coaxial cable, coupler to antenna lead, power supply interface and control interface are firmly installed in the vehicle and an in-situ VSWR measurement is taken to ensure the system is free from interfering sources and EM sensitive devices are physically away from the Transmitter circuits.

IV. EXPERIMENTAL SURVEY OF BEST CONFIGURATION OF COMMUNICATION SYSTEM

To finalyse the configurations of Communication system installation, four options of layout studies were carried out. Best advantages and least tolerable disadvantage of selecting the fourth option as final configuration from EMC point of view and other operational point of view over other options are discussed below;

Option I

Advantages: Minimum distance from antenna to its coupler is maintained for reducing internal radiations. Also EM radiations from coupler [both feed line and casing/housing] are contained within a closed environment.

Disadvantages: HF Radio set is installed over a rotating platform. Also accessibility to its controls is difficult.

Option II

Advantages: HF equipment is conveniently placed and accessibility is also very good from operation point of view. Secondly it is also physically well isolated from VHF equipments and hence better EMC situation with respect to Intra system communication EMI threat.. As required minimum distance from antenna to its coupler is maintained. Here also radiations are contained within close environment.

Disadvantages ; HF equipment is surrounded by a number of non communication electronic subsystems and hence it is closer to dense EM environment**.** Also its compatibility with respect to collocation may definitely pose a problem.

Option III

Advantages: Advantages are same as option II, here the back up battery location to provide stabilised power to Communication system is different from that of option II which is a disadvantage as mentioned below.

Disadvantages: Apart from the disadvantages of option II, there is another disadvantage in this option, that the battery back up location calls for extension of cable routing that could pose some DC drop problem..

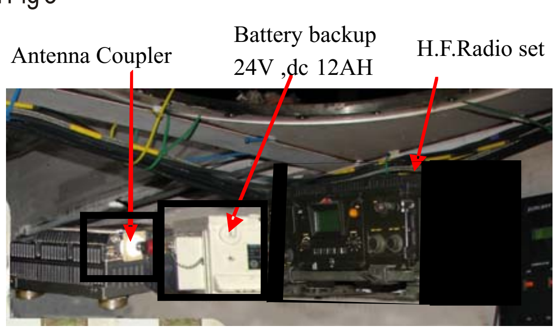
Option IV

Advantages: Much better access to the HF radio set by the operator is fully ensured. Secondly all electrical hard wares of HF radio is confined to an exclusive small compartment. Thirdly HF radio is totally isolated from VHF transmitters/receivers and also other electronic subsystems and hence much better EMC situation is realised. As usual the minimum distance between antenna and its coupler is still maintained. Battery back up is also located closer to radio so that DC drop is not an issue unlike option III.

Disadvantages:

In Order to ensure full protection to HF Radio and its antenna coupler, a separate metallic partition is designed and implemented, because it should not mechanically and electrically disturb the fire control weapon stacking. But this methodology adapted in this option is well accepted, but with an additional cost.

This further revised final Communication system configuration of option IV which is considered as the **best option** from all angles in particular EMC angle is shown in Fig 3



Location of HF Radio set, Battery Backup &

Fig. 3. Commn. System layout configuration - option-iv

V. RF FIELD MAPPING EXPERIMENT

This experiment was carried out with an objective to plot the field strength emitted by the HF radio set under RF power levels viz low, medium and high selection of the set .This enables to rearrange the emitter –receptor pairs of the vehicle in proper locations , so that total EMC is achieved. Depending upon the absolute value of field strength observed for the entire operating frequency range, the decision to rearrange the equipment was taken. Schematic of the test instrumentation used for the field probing inside the vehicle is shown in Fig 4

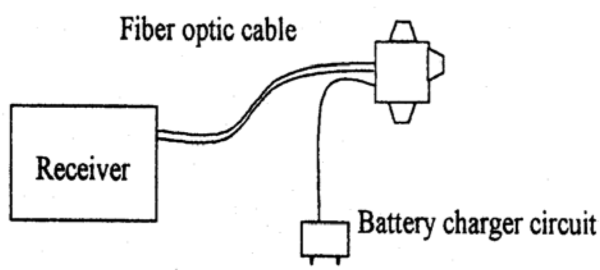


Fig. 4. Test instrumentation for field monitoring

The test Instrumentation essentially comprises of an omni directional E field sensor (There are actually three sensors placed orthogonally in this package which measures Ex, Ey and Ez and outputs the RMS value as an isotropic response).

Field strength in $V/M = \sqrt{E_x^2 + E_Y^2 + E_Z^2}$ (4)

This is connected to a microcontroller based display system using a fibre optic cable (so that the instrument electronics and cable do not introduce direct field pick up error in the measurement) that displays the absolute value of field strength and frequency. This is a programmable device capable of measuring maximum field strength of 300 volts/meter for a very broad band of frequencies 10khz-1000MHz.

VI. COMMENTS ON HF AMBIENT PROFILE

Ambient. EM field inside the vehicle comprises of radiated EM field contributed predominantly by the four non communication electronics subsystems and three communication subsystems ,out of which the HF radio significantly radiates at high RF power, besides power supply disturbances in the form of conducted EMI but this is of less magnitude because there is an effective power line EMI filter at entry point of power to communication system .Also all radio sets contain a built in EMI filter that makes the magnitude of conducted EMI less. Referring to the Fig 5, the major contribution in the frequency region of 1-30 MHz comes from HF radio set.(Also there are contributions from other equipment of the vehicle in this frequency range, but not shown here)

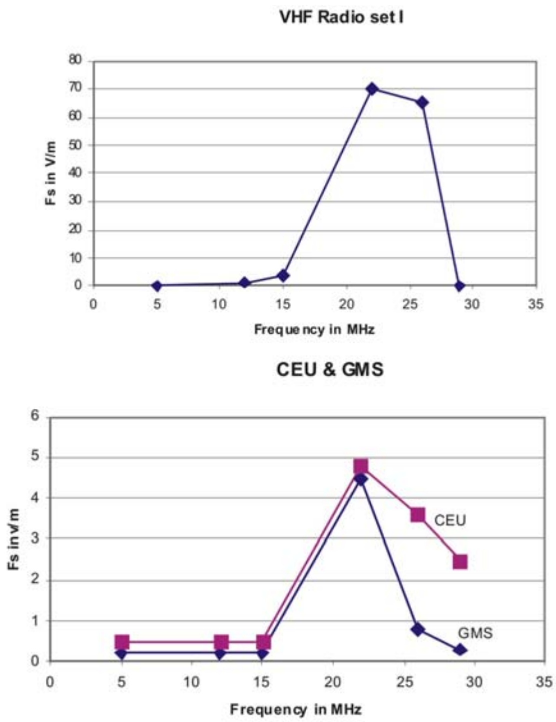
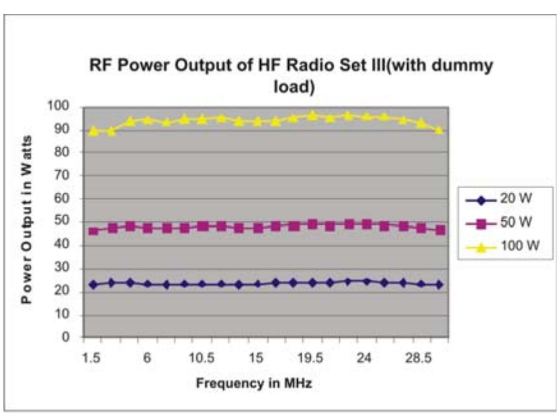


Fig. 5. Ambient profile of the Vehicle (Inside)

VSWR is an important measurement to ensure perfect matching of antenna with radioset. Mismatches contribute to reflections and pulse broadening of carrier frequencies that can radiate in near field zone at appreciable magnitude. VSWR measurement was carried out in the test bench (prior to integration) followed by same measurement in situ in the vehicle (after integration) to ensure the best match is ensured ideal location of HF antenna coupler and antenna was verified by case/cable radiations of coupler and radiation pattern of antenna.



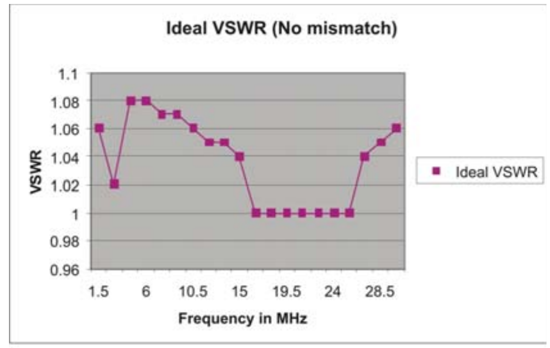


Fig. 6. RF power out put and VSWR plots

Referring to Fig6, we can say that the bench level VSWR has ensured the HF radio is well matched and in situ measurement reveals that there is a slight mismatch that attributes for the reflections and fairly free from metallic objects, otherwise the reflections could have been much higher than what is recorded.

Because of three radio sets operating together simultaneously, inter modulation EMI frequencies [IMI] are generated by different frequencies and their harmonics.(Ref 6).This also contributes for the increase in EMI ambient rise in VHF-UHF region that has an impact on other non communication electronics subsystems. As a whole, unless every radio set harmonics, spurious and emissions from other electronic subsystems are controlled with appropriate EMI hardening measures the ambient will continue to be more than permissible.

VII. CONCLUSION

This study was carried out for the first time in a combat vehicle to prove that locating the high power emitter in dense EMI environment by scientific means provide better performance than attempting by trial and error means employed hitherto. Final .implementation of EMC complied Communication System in the vehicle was carried out systematically establishing a clear procedure for the User to follow .This document has come in handy for the production and inspection engineers to plan the system integration without any ambiguity. The performance of HF radio system is thus established with minimum EMI effects.

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