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Exploration of Electromagnetic Interference (EMI) on Shipboard Equipment

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Abstract**:** ***The purpose of this research is to study about electromagnetic interference, its causes and effect and the effective method for reducing it on shipboard equipment. Electromagnetic interference is an electromagnetic disturbance or recognized as noise that can cause degradation performance of a device or a system on account of high density electromagnetic environment. In this research, a radar system circuit is designed in MATLAB Simulink for simulation and is analyzed by comparing the original signal transmitted by transmitter with the reflected signal on receiver. Radar system was chosen as radar has become one of the most important equipment on board ships.***

Index Terms**:** ***EMI, monostatic pulse radar, simulation, MATLAB Simulink***

I. INTRODUCTION

Electromagnetic interference also known as EMI is the term for the undesired electromagnetic radiation that causes potential interference to the other electronics equipment. There are many methods in which electromagnetic interference can be transmitted from one equipment to another. The key for reducing shipboard EMI is first to identify the source of the offending electromagnetic energy, then to determine a method of correction and, finally, to correct or minimize the effect. The sources of electromagnetic energy affecting shipboard systems fall into four broad categories which are natural EMI, incidental EMI, functional EMI and hull-generated EMI.

There are many methods the electromagnetic interference coupled from the source to the receiver. Understanding which coupling method brings the interference to the receiver is key to being able to address the problem. Radiated EMI coupling type is likely the most obvious. Radiated EMI coupling normally experienced when the source and victim are separated by a large distance ordinarily more than a wavelength. The source radiates a signal which may be desired or undesired and the victim receives it in a way that degrades its performance. Conducted emissions occur when there is a conduction route along which the signals can travel. This may be along power cables or other interconnection cabling.

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The conduction may be two modes which are common mode and differential mode. Common mode occurs if there is noise appears in the same phase on the two conductors while differential mode is when the noise is out of phase on the two conductors.

The filtering techniques required will vary according to the type of EMI coupling experienced. The term of EMI coupled can be one of two forms namely capacitive coupling and magnetic induction. Capacitive coupling occurs when a changing voltage from the source capacitive transfers a charge to the victim circuitry. Magnetic coupling exists when a varying magnetic field exists between the source and victim - typically two conductors may run close together (less than wavelength apart). This induces a current in the victim circuitry, thereby transferring the signal from source to victim.

II. PROCEDURE FOR PAPER SUBMISSION

The scope of work for this project is to analyze a radar system's performance due to electromagnetic interference of the others on-board ship equipment by using MATLAB Simulink software. A basic monostatic radar system is designed in Simulink using Phased Array System Toolbox, Communication toolbox, DSP toolbox and SimRF toolbox. The interference factors are injected into the radar simulation model which act as the EMI. The radar's receiver end will be analyzed to know how interference will affect the signal echoes on a specific target.

III. METHODOLOGY

Proposed Circuit Design

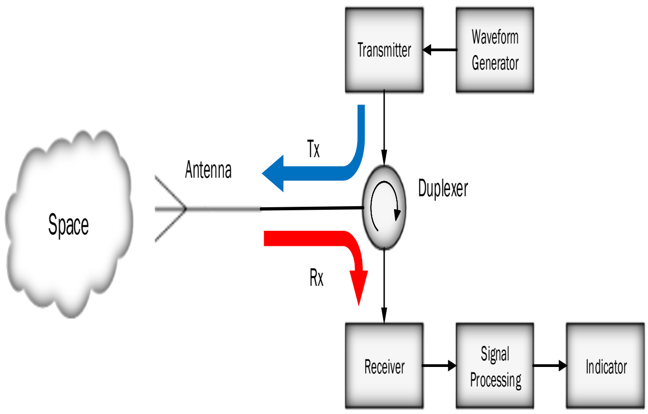

Fig. 1 Simplified scheme of a modern radar system

In this fig 1 show a circuit design proposed [7], it will then be implemented in MATLAB Simulink's blocks. Below are the explanations of the circuit:

a. Waveform Generator - orients the waveform to the environment.
b. Transmitter - a generating tube for a coherent pulse train with high peak power and possibly a wide band
c. Duplexer - RF switch which carry all the energy from the transmitter to the antenna in the transmitting phase while all the energy gathered by the antenna in the receiving phase is sent directly to the receiver chain
d. Receiver - provides frequency conversion, interference rejection and low noise amplification
e. Signal processing - to process the echo signal and extract some information about one/multiple target(s)

End-to-End Monostatic Radar

A monostatic radar consists of a transmitter co-located with a receiver. Fig 2 shows the model of an end to end monostatic radar. The transmitter generates a pulse which hits the target and produces an echo that are received by the receiver. By measuring the time location of the echoes, range of the target can be estimated [12].

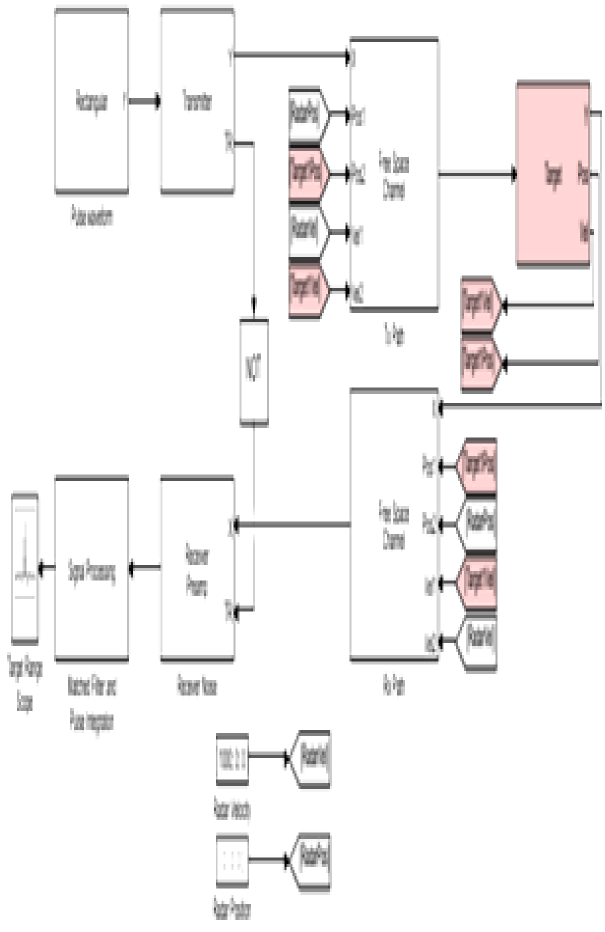

Fig. 2 Model of an end-to-end monostatic radar

This model simulates a simple end-to-end monostatic radar. Using the transmitter block without the narrowband transmit array block is equivalent to modelling a single isotropic antenna element. Rectangular pulses are amplified by the transmitter block then propagated to and from a target in free-space. Noise and amplification are then applied in the receiver preamp block to the return signal, followed by a matched filter [12].

Input parameters coding

Fig 3 shows the input of the parameter coding for the EMI model by using MATLAB.

```
% Environment
    propSpeed = physconst('LightSpeed');   % Propagation speed
    fc = 1e9;              % Operating frequency
    lambda = propSpeed/fc;

    % Constraints
    maxRange = 5000;       % Maximum unambiguous range
    rangeRes = 50;         % Required range resolution
    pd = 0.9;              % Probability of detection
    pfa = 1e-6;            % Probability of false alarm
    tgtRcs = 1 ;           % Required target radar cross section
    numPulseInt = 10;      % Integrate 10 pulses at a time

    % Waveform parameters
    pulseBw = propSpeed/(2*rangeRes);       % Pulse bandwidth
    pulseWidth = 1/pulseBw;                 % Pulse width
    prf = propSpeed/(2*maxRange);           % Pulse repetition
                                              frequency
    fs = 2*pulseBw;

    % Transmitter parameters
    snrMin = albersheim(pd, pfa, numPulseInt);
    txGain = 20;
    peakPower =  ...
        radareqpow(lambda,maxRange,snrMin,pulseWidth,...
                   'RCS',tgtRcs,'Gain',txGain);

    % Matched filter parameters
    hwav = phased.RectangularWaveform(...
        'PulseWidth',1/pulseBw,...
        'PRF',prf,...
        'SampleRate',fs);
    matchingCoeff = getMatchedFilter(hwav);

    % Delay introduced due to filter
    matchingDelay = size(matchingCoeff,1)-1;

    % Time varying gain parameters
    fastTimeGrid = unigrid(0,1/fs,1/prf,'[)');
    rangeGates = propSpeed*fastTimeGrid/2;
    metersPerSample = rangeGates(2);
    rangeOffset = -rangeGates(2)*matchingDelay;
    rangeLoss = 2*fspl(rangeGates,lambda);
    referenceLoss = 2*fspl(maxRange,lambda);

    %Radar parameters
    target1Rcs = 0.5;
    target1Pos = [2000;0;0];
```

Fig. 3 Simulation model input coding

IV. INTERFERENCE FACTORS

In order to analyze the radar simulation model with the presence of EMI which act as noise in the simulation model, there are several types of noise that are injected into the simulation model. In the Simulink Library, there are many noise function blocks that can be inserted into the simulation model. However, the noise functional blocks that are chosen to be analyzed together with the simulation model are AWGN, phase noise and thermal noise. These type of noise are the most commonly exist in the environment of navigation deck on board ship that mainly comes from radio sets, oscillators and thermal vibrations in conductors. So these noise functional blocks are injected into the model to find out the effect to the radar's return signal output.

Additive White Gaussian Noise (AWGN)

AWGN is the abbreviation of additive white Gaussian noise which is a basic noise model used in information theory in order to imitate the effect of many random process that occur in nature.

Phase Noise

Phase noise is the random jitter in the time-base for a radar; the basic oscillator or clock reference signal.

Since the radar is not aware of its timing jitter, it attributes the randomness to the received echoes. Therefore, phase noise manifests itself in radar as a modulation of the echo delay time of a target.

Thermal noise

The noise in a receiving system that is coming from the radar electronics is called internal noise or thermal noise. It can be a result of random movement of electrons in the circuitry or any other noise-generating processes that arises from blackbody radiation from the atmosphere, cosmos and the Sun.

V. SIMULATION RESULTS

Original output signal

By using the initial parameters set for the radar model, the output at the target range are as Fig 4. The target radar's return signal was clearly detected as the amplitude of the signal is high enough to distinguish it from any noise that appear on the scope.

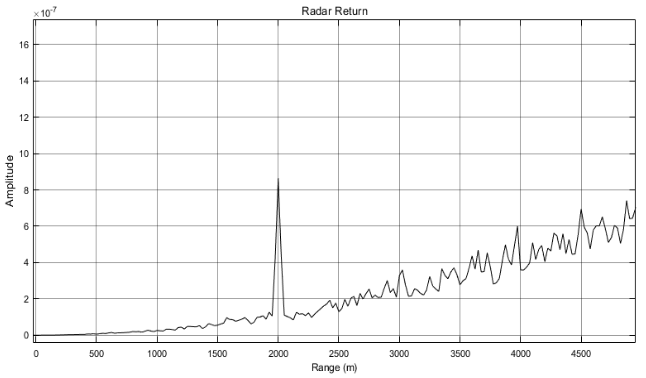

Fig. 1 Original output signal

Additive White Gaussian Noise (AWGN)

As shown in Fig 5 until Fig 7, the radar's return signal output varies from lower value SNR to higher value SNR. Starting from 10 dB set up which is the lowest value, the radar's return is completely undetectable. The signal cannot be considered acceptable due to very high noise exist in the system. The same output signals are resulted from the SNR value set as 30 dB though the signal gradually becoming similar to the original signal output and the return signal can be distinguished from the noise and can be seen quite clear. For the SNR of 45 dB, the radar's return signal are very clear with very little that it can be ignored. So, obviously higher SNR generates higher visibility of radar's return signal.

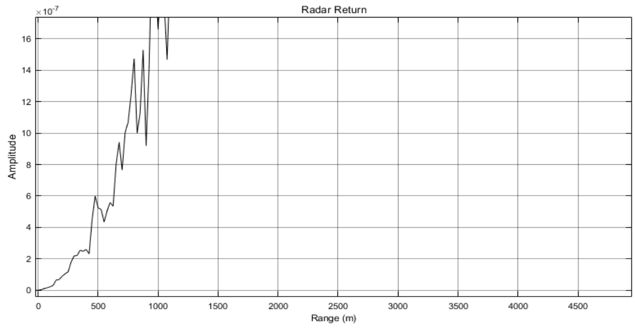

Fig. 5 SNR (dB) = 10

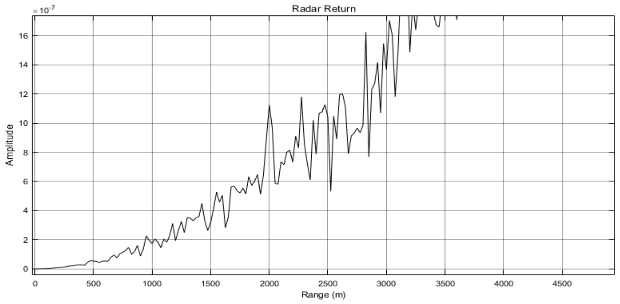

Fig. 6 SNR (dB) = 30

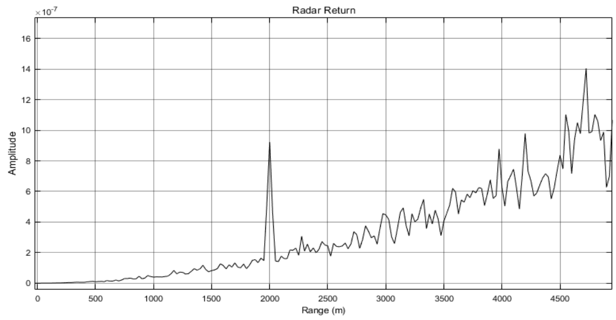

Fig. 7 SNR (dB) = 45

Phase Noise

By adjusting the phase noise level, the radar's return signal output are as shown in Fig 8 until Fig 11. From the results, the radar's return signal has minor changes. The amplitude of the radar's return signal has slight difference when compared to each other. When phase noise level is set up between -10 and -10 dBc/Hz, the peak value of the amplitude declined a bit compared to the original result. However, the amplitude value of -30 to -30 are almost approaching the amplitude value of the original result. There are also difference of the amplitude value between phase noise level of -10 to -100 dBc/Hz and -100 to -10 dBc/Hz. Phase noise level of [-10 -100] has the same amplitude value as the original while phase noise level of [-100 -10] has reduced amplitude value compared to the original result. Based on the result of the simulation, phase noise level are varied causing the amplitude value also changes but the radar's return signal are still can be seen clearly thus phase noise has minimum effect to the radar's return signal.

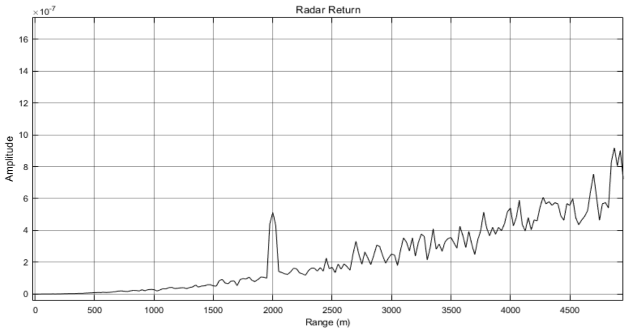

Fig. 8 Phase noise level (dBc/Hz) = [-10 -10]

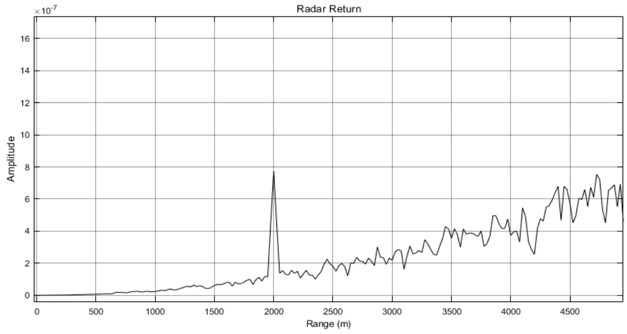

Fig. 9 Phase noise level (dBc/Hz) = [-30 -30]

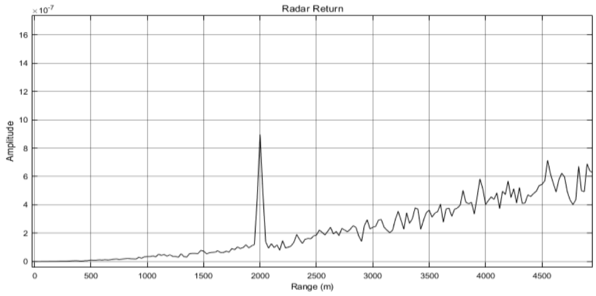

Fig. 10 Phase noise level (dBc/Hz) = [-10 -100]

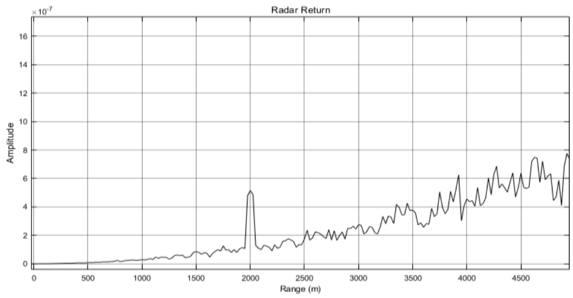

Fig. 11 Phase noise level (dBc/Hz) = [-100 -10]

Thermal noise

Based on the Fig 12 until Fig 14 that have been simulated, when the noise temperature is set to room temperature that is 290K, the radar's return signal are identical to the original result. As the noise temperature is increased, the signal slowly and gradually becoming undetectable. The 2500K noise temperature has its signal output vary high intensity of noise towards the increasing of range. Same result goes to the 5000K noise temperature with higher intensity of noise which make the radar's return signal difficult to distinguish. Escalating with the increase of noise temperature, when it is set for 10000K, radar's return signal is completely loss due to noise.

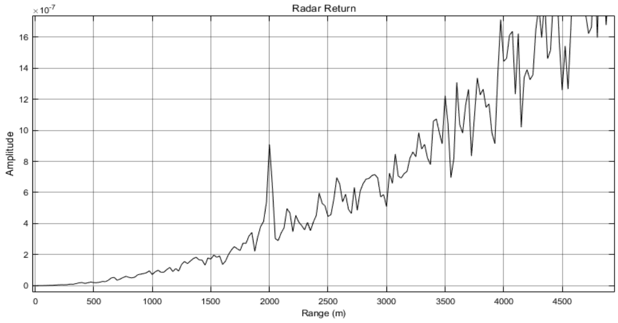

Fig. 12 Noise temperature (Kelvin) = 2500

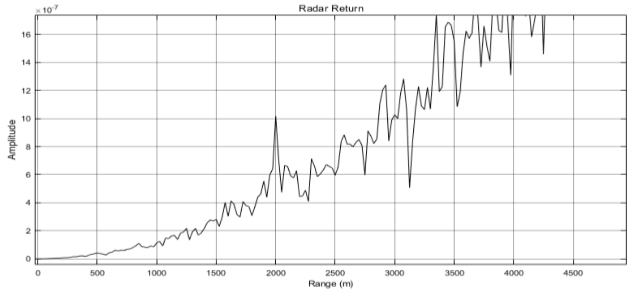

Fig. 13 Noise temperature (Kelvin) = 5000

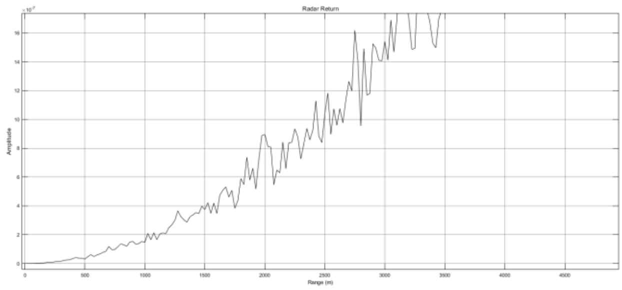

Fig. 14 Noise temperature (Kelvin) = 10000

VI. CONCLUSION

In conclusion, EMI has become one of the most significant factors in radar system for it to be operated in its maximum reliability and efficiency. EMI must be able to be predicted and then is suppressed by analyzing its sources, performing the method for reducing the EMI issue and testing for reaching the EMC. This project has been using only one type of radar model which is monostatic radar with only a static target and with decent usage on EMI that is injected into the radar model. Since this is simulated-based project, testing on a real vessel is highly recommended in obtaining real-time results which can help for commercialization purpose.

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