2005 ASIA-PACIFIC CONFERENCE ON APPLIED ELECTROMAGNETICS PROCEEDINGS, December 20-21, 2005, Johor Bahru, Johor, MALAYSIA

Conceptual Implementation to Access the Extend of Influence of Lightning Electromagnetic Radiation on Mobile Radio Communication

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Abstract--In this paper, the research of interference to the private mobile radio (PMR) due to lightning electromagnetic field has been done. The conceptual implementation to access the extend of influence of lightning electromagnetic radiation (LEMR) on mobile radio communication. Wireless data has been transmitted through a pair of Motorola Talkabout T5420 walkie-talkie with 14 channels and 38 codes and operates on 14 UHF FRS Frequencies. Two types of induced interference has been arranged which are high voltage and high current experiments using Impulse Voltage Generator (IVG) and Recloser Test Set (RTS) in High Voltage Laboratory, Institute of High Voltage and High Current, UTM.

1. Introduction

Wireless communication technology has developed and more reliable in order to communicate with other people around the world. In transferring the data from one end to the other end, especially in wireless and mobile data transmission, the expected data at the receiver should be the same as from the transmitter. Otherwise, the data will not be classified as a reliable data.

However, the development of this technology is still unable to preserve their reliability from several natural phenomena such as rain drops, storm and lightning effects. In telecommunication, the sequence of rain on the microwave system at a particular frequency is more critical especially for the countries located in tropical and equatorial region (Din J. et. al, 2003) and so as lightning.

Lightning plays a role as a major natural force of electromagnetic radiation and the ability of transmitting data to the receiver become unreliable. A lot of research has been done to conserve the data during the transmission after it being influenced by this kind of natural prodigy. Therefore, a reliable and dependable data can be accumulated at the receiver.

From figure 1 is the overall view of this research. A couple of walkie-talkie will be used to transmit and receive data. A pair of walkie-talkie will be connected to the computer. One pc will generate and transmit the data and another one will be used as a receiver and it will retrace back the data

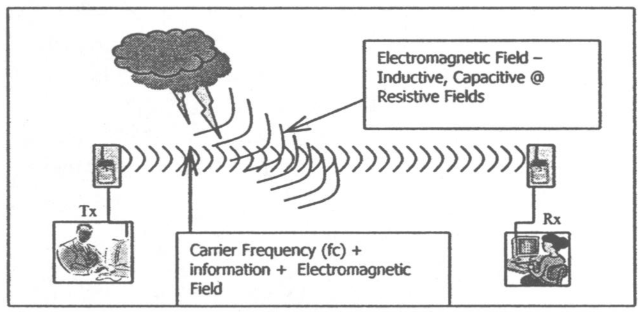

Figure 1: Overall figure of research

Unfortunately, along the propagation path, the frequency is barely affected by the natural sources of phenomena such as rain or lightning. In this case, a sudden lightning occurred or an artificial lightning is induced in the middle of transmission, the lightning will produce the electromagnetic field which consists of inductive, capacitive and resistive field. The interaction between these two fields will cause interference and corruption of data (Golam Sorwar, 1997). The research is lead to investigate kind of interaction between these two fields

2. Frequency Shift Keying (FSK) Signal

The FSK signal is defined as

$$x(t)=\begin{Bmatrix} x_1(t)=A\cos 2\pi f_1 t \\ x_0(t)=A\cos 2\pi f_0 t \end{Bmatrix} 0 \le t \le T_b \qquad \begin{matrix} s = 1 \\ s = 0 \end{matrix} \qquad (1)$$

The signal that been defined is generated in time domain will only be two possibilities which are determine by X_1 and X_0 that give value 1 or 0. T_b is the time interval, A is the amplitude of the cosine signal and f is the frequency. The conceived signal is in digital form so that the analysis of signal can be conducted efficiently (A.Z. Sha'ameri).

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3. Bit Error Rate

One of the changes that modern digital communications systems have brought to radio engineering is the need for end-to-end performance measurements. The measure of that performance is usually bit-error rate (BER), which quantifies the reliability of the entire radio system from "bits in" to "bits out," including the electronics, antennas and signal path in between. On the surface, BER is a simple concept and its definition is simply:

BER = Errors/Total Number of Bits

With a strong signal and an unperturbed signal path, this number is very small as to be insignificant. It becomes significant when need to maintain a sufficient signal-to-noise ratio in the presence of imperfect transmission through electronic circuitry (amplifiers, filters, mixers, and digital/analog converters) and the propagation medium (e.g. the radio path or optical fiber). Any in-depth analysis of the processes that affect BER require significant mathematical analysis (Gary Breed, 2003).

3.1 Q Function

Calculation of bit error rate can be done in two ways. First method to define BER is using Q function. This function is difference for difference type of signals. For coherent frequency shift keying (fsk) signal, the BER is derived by first calculating the γ^2 that is then substituted in the Q function (A.Z. Sha'ameri).

Where $\frac{1}{(f_1 - f_0)} < T_b$, if the value of $(f_1 - f_0)$ is very large it will result the γ^2 and γ to be as follows:

$$\gamma^2 = \frac{1}{N_0} A^2 T_b$$

$$\frac{\gamma_{max}}{2} = \frac{1}{2}\sqrt{\frac{A^2 T_b}{N_0}} = \sqrt{\frac{A^2 T_b}{4N_0}} \qquad (2)$$

Finally, the BER of coherent fsk can be calculated using this Q function.

$$BER = Q\left(\sqrt{\frac{A^2 T_b}{4 N_0}}\right) \qquad (3)$$

where T_b is time interval during transmission and N_0 is additive noise power at 0. The calculation of BER for non coherent fsk signal is also can be determined using those formula

$$P_e = \frac{1}{2}\exp\left(-\frac{A^2}{4N_p}\right) \qquad (4)$$

where the filtered noise power is

$$N_p = 2 N_0 r_b = \frac{2 N_0}{T_b} \qquad (5)$$

where r_b is the bit-rate, T_b is the bit-duration, and N_0 power of the additive white noise.

4. Experimental Setup

In order to identify the loss of data or error of the bit transmitted through the medium, several equipments are needed. The experiment consists of two important equipments which are:

1. Impulse Voltage Generator (IVG) for high voltage and low current artificial lightning strike
2. Recloser Test Set (RTS) for high current and low voltage artificial lightning strike

For high voltage experiment, the radio is placed inside the control room and the other one at the outside of the border. This is to make sure that both of the radios applied the line of side (LOS) condition. The distance between two radios is 5m. The experimental setup for this experiment is shown in Figure below.

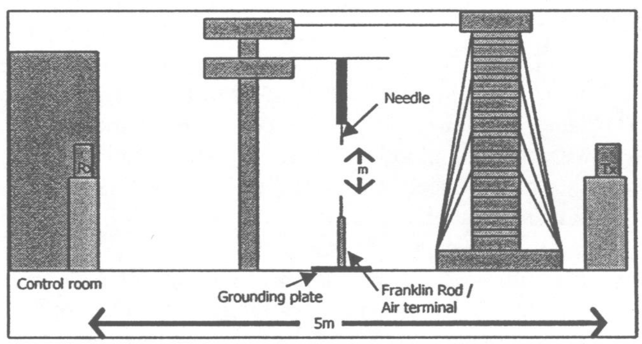

Figure 2: The side view of the high voltage experiment layout

In the second experiment RTS is used in order to determine the effect of high current to the transmitted signal. The layout of experiment is shown in figure 3 and 4.

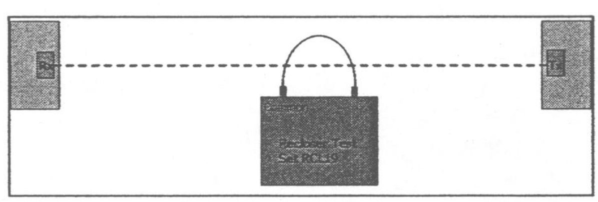

Figure 3: The plan view of the high current experiment layout

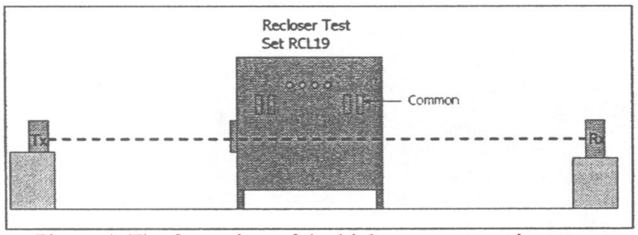

Figure 4: The front view of the high current experiment layout

5. Result and Analysis

5.1 Generation of FSK Signal

As discussed above, fsk modulation method is used in order to accomplish a transmitted signal.

a. 2 base band signal frequencies;
   i. Upper frequency, f1 that will represent bit 1; in this case 1600Hz will be used to this frequency.
   ii. Lower frequency, f0 that will represent bit 0; and for this case 1000Hz is choose for this frequency.
b. Bit rate is set to 100. This value will determine the time for 1 bit generated in time domain. That's mean; every1 bit will took 0.01s or 10ms.
c. Sampling frequency, f_s is set to 8000Hz. This is a normal value of sampling frequency since the sampling time is 125μs.
d. Sequence of binary data, S. For this case, 1000 bit of binary data is employed in order to generate a 10seconds of fsk signal.

This experiment required sequence of 1000 bit binary by using the initial parameters stated above. Total time taken to represent 1000 bits will be 10 seconds or 10000ms. It will represent 1 packet of signal.

5.2 No Lightning Condition

Before the two main experiment were been conducted, the no lightning condition was considered. From figure 5, 3 full packets of signal managed to be stored. The other packets that are not fully 1000 bits will be ignored. As can be in the same figure, the frequency of signal can be seen clearly at 1000Hz and 1600Hz. This result will be used to compare with the result in high voltage and high current experiment in term of error of the bit or other types of interferences. The data accumulated from this result will also be analyzed and it will become the reference point of the other experiment analysis results.

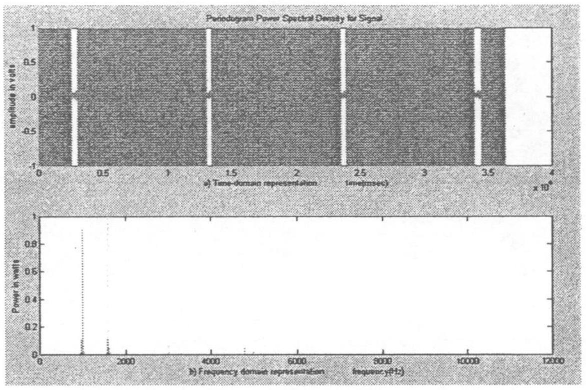

Figure 5: Time and frequency domain of received signal when no lightning condition

5.3 High Voltage Experiment – Using IVG

In the first experiment, 2 tests managed to be executed which are at 170kV and 400kV. The limitation of undergoing further than this two voltage value is due to the unavailability of insulator. From the result of these two values, it can be concluded that no error of bit is discovered. Figure 6 and 7 shows the received signal in time and frequency domain.

In the frequency domain representation for both tests, it is obvious that both frequencies are still able to be obtained. The only different is that the signal strength of 400kV is less than 170kV for the frequency of 1000Hz. Moreover, for the frequency 1600Hz, the signal strength of 170kV is less than 400kV. It shows that, even there is no sign of error of the bits, but the signal strength in term of pwer in watts is decreased due to the induced voltage ocompared to no lightning condition.

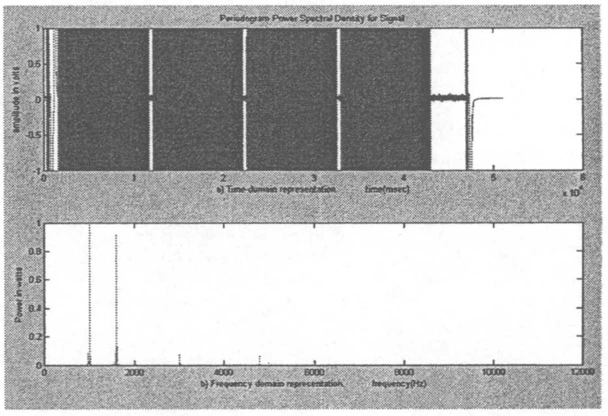

Figure 6: Received signal when 170kV is induced to the transmitted signal

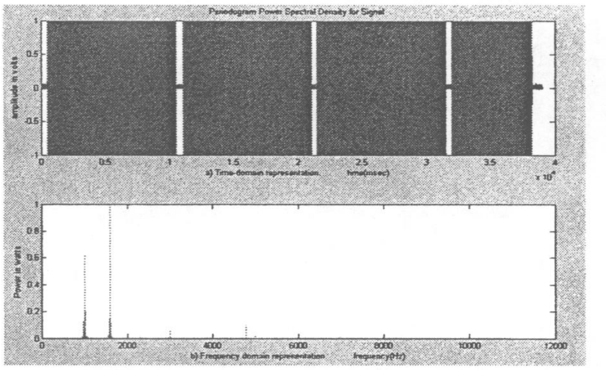

Figure 7: Received signal when 400kV is induced to the transmitted signal

In the high current experiment, several sets of test have been conducted starting from the lowest input current to the highest value 200A, 250A, 440A, 650A, 720A, 850A, 1500A & 2000A.

5.4 High Current – Using RTS RCL19

In the second experiment, from 8 of current values, losses of bit are identified at 3 current values which are 440A, 850A and 2000A. Losses of bit mean that the receiver does not capture either bit '1' or '0'. The receiver only detected zero amplitude as can be seen in figure. In figure 8, for current value 650A, no bit loss is identified but in figure 9, bit loss is exposed at the first packet.

When current input value is set at 440A, total bit loss is 251.72ms in the third packet. While current input value is set at 850A, total bit loss is 251.30ms in the second packet and lastly when current input value is set at 2000A, total bit loss is 250.10ms in the first packet as shown in figure 9. If one bit is represent by 10ms, therefore total bit loss in this three current value is 25 bits. Since the total of full packet of signal is 10 seconds, total bit loss in each current value approximately 2.5%. The bit loss is 25 bits out of 1000 bits which means the bit loss rate is 0.025 or $2.5\text{x}10^{-3}$.

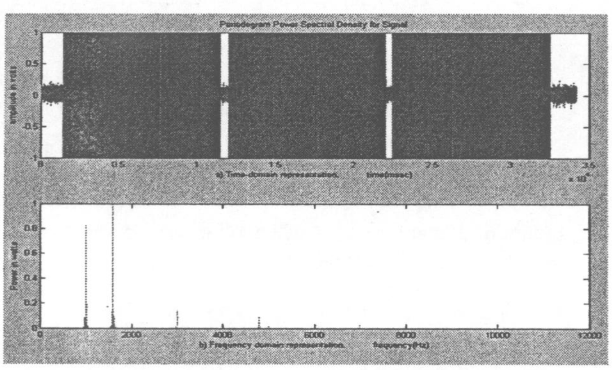

Figure 8: Received signal when 650A is induced to the transmitted signal

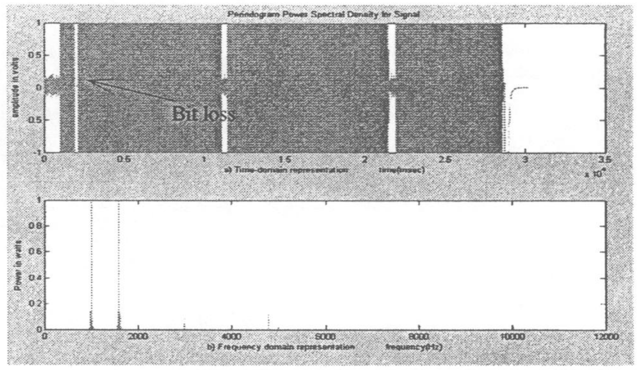

Figure 9: Received signal when 2000A is induced to the transmitted signal

5.5 Overall Experiments

In all experiments and tests, there are some issues that contribute to the limitation or disturbance to undergoing the tasks. The limitations are:

a) The sensitivity of modified cable is unpredictable. This is due to the internal connection of the cable itself.
b) Synchronization between data transmission and voltage charging and discharging must be put under consideration in order to make the analysis easier.
c) Time taken to analyze the received data. The received signal is stored as '.wav' file. The issue is that one '.wav' file took more than 2 hour to be analyzed due to the size of the file. The longest hours that taken is almost 24 hours!

The most important finding is the delay of received signal is detected. The table 1 below described the delay for each of the voltage and current values including the no lightning condition. This is because comparison can be made easily.

Table 1: Total delay of every packet received at the receiver

	Total Delay (ms)			Maximum delay (delay – min. delay)
	Packet no. 1	Packet no. 2	Packet no. 3	
No lightning	18.7	18.0	19.0	1.0 ms
170kV	19.3	18.0	18.1	1.3 ms
400kV	19.1	18.9	20.0	2.0 ms
200A	24.5	24.7	26.6	8.6 ms
440A	28.9	26.5	24.8	10.8 ms
650A	29.2	24.8	29.1	11.2 ms
720A	24.8	24.3		6.8 ms
850A	25.0	25.0		6.0 ms
1500A	24.4			6.4 ms
2000A	24.6	24.4		6.6 ms

Originally, the data set to 10 seconds, however, due to the losses described above, the received signal experienced delay up to 20ms or less depends on the distance and frequency used. From the table, delay is recognized for the transmission of data through the higher current compared to no lightning condition. On the other hand, no delay of received signal for high voltage experiment. Maximum delay compared to original transmitted data is 29.2ms & if compare to no lightning condition, maximum delay is 11.2ms at current value of 650A.

6. Conclusion

As the conclusion for the first experiment, only 2 tests managed to be conducted that is the data transmission with the induced voltage of 170kV & 400kV in the middle of transmission path. The reason that only two values of voltage used is due to the unavailability of insulator to insulate the IVG. The results have found that no error or loss of bit has been identified and not much of delay been exposed. Maximum delay of received signal compared to no lightning data transmission is 2.0ms.

For the second experiment, it can be concluded that 8 has been analyzed started with 200A, 440A, 650A, 720A, 850A, 1100A, 1500A and 2000A. From the results, loss of bit has been identified at the current value of 440A, 850A and 2000A. Total bit loss for those three current values is 25 bits or 0.025% loss out of 1000 bits of binary data. Furthermore, delay of received signal in high current experiment has also been exposed compared to no lightning condition. Minimum delay of received signal (for no lightning condition) is 18.0ms. Maximum delay of received signal compared to original 10seconds data is 29.2ms. Maximum delay of received signal compared to no lightning condition is 11.2ms

As the final conclusion, in telecommunication nowadays, an accurate data transmission is the most expected in developing countries. In this proposal, literature reviews of the effect of lightning electromagnetic field radiation to the mobile data transmission have been presented. The results of the research can be used as the basis for improving the performance of mobile transmission system especially in environment where there are high lightning activities. This is can be executed by proper placing of microwave repeater towers on hilly area which are less prone to lightning strikes.

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