The Research on the Simulation of VHF Radio Broadcasting Loss

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Abstract. VHF radio is a crucial part of the communication system in the battlefield. Since that the paper has adopted the idea of hierarchical modelling, and aiming at building up a simulation model of VHF radio accordingly, which is described with CCIR model, and the elevation data is presented with topographical map. Finally, the battlefield simulation of VHF radio is implemented with OMNET++. The result of simulation validated the credibility of the method, which would provide the simulation of battlefield in complicated electro-magnetic environment with new practical approaches.

1. Introduction
VHF radio is the acronym of very high frequency radio, which means a radio with a working frequency of 30–300MHz. Comparing with other communication methods, the VHF radio has its unique advantage of low maintain costs, and fast networking application, ranking it among the important battlefield communication network components. The common VHF radio including handheld VHF, backpacking VHF and vehicle-mounted VHF. Adopting the signal mechanism that is adjusted to the trunk network, VHF radio realized the function of encounter to access, which means higher battlefield performance and resistance to disturbance [1]. However, VHF signals are often influenced by terrain factors, more suitable for short distance communication.

According to the features of VHF radio, a simulation model of battlefield VHF radio is built up with OMNET++, and its cover characteristics is calculated by taking broadcasting losses and DEM data matching into consideration. This would be a practical reference for the designing of the simulation of complicated electro-magnetic environment.

2. The Simulation Model of VHF
The simulation model of VHF radio has its unique hierarchical structure, and every layer has the interface and communication protocol of its own. By combining different protocol models, or allocate the models of different layer to the proper layer, a equipment level simulation system of network nodes could be built up accordingly. Similarly, a platform level of network simulation could be built up with a combination of network equipments, and a network level with a combination of network platforms [2].
The design of a VHF radio should take many features into concerns, such as frequency, power, sensitivity, bandwidth, data rate, modulating method, frequency table (subnet number), hop rate, routing algorithm, access method, decline model. With those parameters, the simulation model of VHF radio of different performance could be built. Figure 2 is the design diagram of VHF radio simulation.

The function of every components of the radio’s simulation model is shown in table 1.
### Table 1. The description of all the components of the simulation radio

| Function                  | Description                                                                                                                                                                                                 |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Management modulator      | Responsible for radio control, including the initiation and implementation of the synchronization function of frequency table and address list, and packing and unpacking of the data packets, control packets, and routing query for data packets. |
| Routing modulator         | Responsible for the implementation of routing function, including the reception and distribution of routing information, and routing calculation, and the routing query interface.                                    |
| MAC modulator             | Provides the access to data link layer, including sizing up the resources, the control of physical layer, and the packaging of MAC layer telegram.                                                             |
| PHY                       | The simulation of transmission mechanism of the physical layer, including physical layer framing and decoding, modulation and demodulation simulation, bit error performance simulation, noise performance simulation, interference, anti-interference performance simulation, transmission performance simulation. |
| Hop rate management modulator | The management of radio hop rate features, including the settings of frequency table, the control of frequency hopping features.                               |
| Adaptation modulator      | The data interface for the telegram translation and adaptation or control(such as SLIP or Ethernet port, K port).                                                                                             |
| Address mapping table     | Including the mapping table of data storage device address and radio address, the query interface of address mapping, supporting IPv4 address, IPv6 address, prolonged non-IP address, and other forms of addresses. |

According to the idea of hierarchical modeling, the paper selected a typical VHF radio, and built up a simulation model of it. The structure is shown as figure 3.

![Figure 3. Simulation model of VHF radio](image)

At the same time, the simulation parameters of VHF radio model are designed. Through the configuration of model parameters, VHF radio with different performance can be simulated, so as to be flexibly applied in network simulation \[^{3,4}\].
Table 2. The parameters of VHF radio model

| Name                  | Type   | Default value | Range              | Notes                                                                 |
|-----------------------|--------|---------------|--------------------|----------------------------------------------------------------------|
| broadcasting Model    | string | Two-Ray       | The decline model  | Decline model                                                          |
| bandwidth             | double | 1MHz          | 512KHz~2MHz        | Have an influence on the performance of signal transmitting distance, bit rate, disturbance resisting, and etc |
| Trans Power           | double | 20W           | Non-negative       | Transmission power rating, the higher the power is, the longer the signal travels. |
| Antenna Height        | double | 3m            | >0                 | The height of radio antenna, the higher antenna, can receive signal from more distant away |
| Channel Number        | int    | NULL          | [1,2320]           | The channel number of radio. The entire available frequency is separated into several channels, and the band resources would ne reused. |

3. The Broadcasting Model of VHF Radio

VHF radio band signal can not be reflected by the ionosphere, and it can only be used for communication through a straight line. In the process of linear transmission, there are many factors that may affect the signal. Firstly, loss attenuation occurs in the signal transmission process, even in the absence of other attenuation or damage sources, cross-distance signal transmission will be attenuated, because the signal will distribute in an increasingly large area with the increase of distance, and The farther the antenna is from the transmitting antenna, the lower the received signal power. This form of attenuation becomes free space loss, which is inevitable, and this attenuation is closely related to the topography. Secondly, the bit error of the message in the transmission process, in order to improve the reliability of signal transmitting, or to reduce the bit error rate, the most commonly used method is to use channel coding. Finally, noise, atmospheric absorption, multipath, refraction and other factors will also affect the linear transmission of signals [5].

CCIR (Comité Consultatif International des Radio-Communications, also known as ITU-R) is an empirical formula that takes into account the combined effects of path loss in free space and path loss.

\[
L_{CCIR}(dB) = 69.55 + 26.16 \log_{10} f_{MHz} - 13.82 \log_{10} h_1 - a(h_2) + (44.9 - 6.55 \log_{10} h_1) \log_{10} d_{km} - B
\]

Here \(h_1\) and \(h_2\) are the height of base station and the mobile node (unit in meter), \(d_{km}\) is the length of link (unit in kilometer), and \(f_{MHz}\) is center frequency (unit in MHz).

\[
a(h_2) = (1.1 \log_{10} f_{MHz} - 0.7)h_2 - (1.56 \log_{10} f_{MHz} - 0.8)
\]

\[
B = 30 - 25 \log_{10}(\text{Percentage of the area occupied by buildings})
\]

The formula is the broadcasting condition of Hata model for the media or tiny sized cities, complemented with an adjust factor \(B\), in the urban area \(B=0\), which means the area occupied by buildings is about 15%. For example, if 20% of the area is occupied by buildings, then

\[
B = 30 - 25 \log_{10} 0.20 = -2.5dB
\]

In the model, the percentage is set to 15.8 as a default value, used for the media or tiny sized cities exclusively. The range of the CCIR model application: the height of base station antenna is 20-300 m, the height of mobile terminal antenna is 1-10 m, the effective distance between the base station and mobile nodes is 1-20km. The frequency of the signal center is 150-1500 MHz. And the lose value along its broadcasting path is as figure 4.
4. The Simulation of Battlefield Terrain

The terrestrial battlefield environment is mainly composed of natural environment, human environment, economy and transportation, battlefield communication and city. Through collecting, processing, modeling and saving the elements of land battlefield environment, the information is managed in the form of database, and the external output interface is provided to facilitate users to read and apply the information. Geographic information and battlefield environment simulation are inseparable. Geographic information is the fundamental data of battlefield environment simulation, and the environment simulation of large battlefield is often presented in the form of GIS.

If the terrain attribute in a digital terrain model is elevation it is called Digital Elevation Model (DEM). From a mathematical point of view, the elevation model is a continuous function of the elevation \( Z \) with respect to two independent variables \( X \) and \( Y \), and the digital elevation model (DEM) is only a limited discrete representation of it. As a matter of fact, the topographic model contains not only elevation attributes, but also other morphological attributes, such as slope, aspect, etc. DEM is usually expressed by the elevation matrix composed of regular grid elements. Generalized DEM also includes all the digital representations of elevation such as contours and triangles.

The contour model makes use of the known set of elevation values to represents elevation. Each contour line corresponds to a known elevation value. Thus, a series of contour sets together with their elevation values form a ground elevation model. Contours are usually stored as an ordered sequence of coordinate point pairs, which can be considered as a simple polygon or polygon arc with elevation value attributes. Because the contour model only expresses part of the elevation value of the region, an interpolation method is often needed to calculate the elevation of other points outside the contour line, and because these points are located in the area surrounded by two contours, so only the elevation of the two contours outside the contour line is usually used for interpolation.

The paper put out a drawing method of DEM with the contour. Figure 5 is the contour drawing flow chart, and Figure 6 is the contour map after DEM data contour processing.
Follow the trace to draw a non-closure contour line, and delete the triangles used in the TriContourArray.

Points of the same elevation value in the border table?

Yes

Follow the trace to draw a non-closure contour line, and delete the triangles used in the TriContourArray.

No

Take out the triangles, follow the trace to draw a non-closure contour line, and delete the triangles used in the TriContourArray.

TriContourArray is NULL?

Yes

Drawing a closed contour line.

No

All the contour lines have been generated?

Yes

End

Figure 5. The flowchart of generation of the DEM contour lines

Figure 6. The contour map generated with DEM elevation data

5. The Simulation of VHF Instantiation Model

According to the simulation model and parameters of a VHF radio referred above, the working frequency, signal channel number, bandwidth, and other performance is shown as follows in table 3.

Table 3. The performance of VHF radio simulation model

| Parameter items       | Performance index | Remarks                                                                 |
|-----------------------|-------------------|-------------------------------------------------------------------------|
| Working frequency     | 30MHz-88MHz       | N/A                                                                     |
| Signal channel number | 2320              | N/A                                                                     |
| Signal channel gap    | 25KHz             | N/A                                                                     |
| Signal channel center frequency | (30+0.025n-0.0125 MHz | N is the signal channel number of VHF, range of value is [1-2320]. |
| Transmission bandwidth| The maximum is 64Kbps | The capacity of transparent data channel is up to 64Kbps, but actually, the real transmission rate is lower, due to the loss of lower protocols. |
| Modulation mode       | BPSK              | N/A                                                                     |
| Multi-address mode    | CSMA              | N/A                                                                     |
| Networking mode       | Ad Hoc            | Realize the multi-hopping network with Ad Hoc mode, routing protocol is FSR. |
| Data interface        | K                 | The K interface provides a series of transmission rate, such as 9.6Kbps, 19.2Kbps, 38.4Kbps, 64Kbps and so on. |
| Effective communication distance | Low power: 14Km; middle power: 22Km; high power: 39Km | The recited values are theoretical values. In the case of simulation, the calculated values may varies a bit. |
| Subnet scale          | 16                | The max number of nodes in a single subnet. |

Figure 7-9 show the electro-magnetic coverage as the broadcasting power of the simulation model of VHF radio is 5W, 10W, 20W separately.
6. Conclusion
The paper implemented the simulation model of VHF radio and studied its coverage feature in the simulated environment based on the OMNET++ platform, with the CCIR broadcasting model, and DEM elevation data. The result of simulation indicated that the method is very effective, which would provide new approaches for the simulation of battlefield in complicated electro-magnetic environment. And the writer is eagerly looking forward to hear all the constructive advices.

7. References
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