A Study of NVIS for Communication in Emergency and Disaster Medicine

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Abstract

In the case of disaster and emergency situation, communication infrastructure availability is one of the key points for success of telemedical services: coordination among the medical personnel, monitoring of evacuation or treatments to the patients. However it is often happened that telecommunication infrastructure is not functioning in this situation because of damage or malfunction due to disaster or blockage because of high traffics, which is typical in cellular system.

HF communication gives a good possibility to communicate during disaster, as it is cheap and easy to establish. The Near Vertical Inclined Skywave (NVIS) is a HF method to reach area at the radius between 80-113 km from the sender. This area is normally not reachable by the ground wave communication or conventional HF communication.

This paper discuss about the features of NVIS communication and performance simulation.

Keywords:
Communication in Disaster Medicine, NVIS

1. Introduction

Advancement in the telecommunication and information infrastructure provides wide range of services. Underlying this explosion is a dense web of network including the global telephone network and the Internet, which day by day provide better bandwidth and accessibility. Almost all activities become more highly depend on telecommunication facilities, and if some problems happen with the facilities, the will greatly produce difficulties.

Disaster including natural disaster or man-made disaster can sever segments of the backbone network. In the event of nuclear disaster for example, Electromagnetic Pulse (EMP) will be emitted and reach to the long distance which is not physically influenced by its explosion. It was reported that due to nuclear explosion test by US in 1962 setting off near Johnson Island in the Pacific Ocean, over 800 miles from Hawaii, caused much problem. The EMP was strong enough to reportedly set off scores of burglar alarm, foul telephone switching equipment, and temporarily disrupt power utilities and radio stations throughout Hawaii [1].

Telecommunication infrastructure, mostly include very large-scale integrated circuit (VLSI) components. Modern VLSI chips are extremely sensitive to voltage surges and can be burned out by even small leakage current [1]. Overcoming the effects of this man-made disaster as well as natural disaster, there is a need such communication link which easy and fast to deploy, and provide link in the area of 100-300 km apart. Near Vertical Inclined Skywave (NVIS) communication in HF band seems promising to cover it, for both voice and low bit rate data.

Based on this needs, the objective of this paper is to investigate NVIS mode in emergency and disaster medicine, to support communication in those fields, with difficult condition and situations. NVIS concept, benefit and limitation first will be described in the next chapter, following by discussion about the performance issues, and evolutions by simulation, discussion and conclusion.

2. Near Vertical Inclined Skywave Propagation

HF communication has been used for years. Low cost long-distance communication can be achieved by utilizing the benefit of natural behaviors of ionosphere layers. Under ideal conditions, ground wave component of a radio wave becomes unusable beyond radius 80 kilometers [1]. This range can be much less due to ground terrain in the actual condition. Sky waves, which efficiently launch the sky wave, on the other hand, will not return to earth at a range of less than 161 kilometers. This can leave a skip zone of at least 80 to 113 kilometers where HF communications will not function (Figure 1).

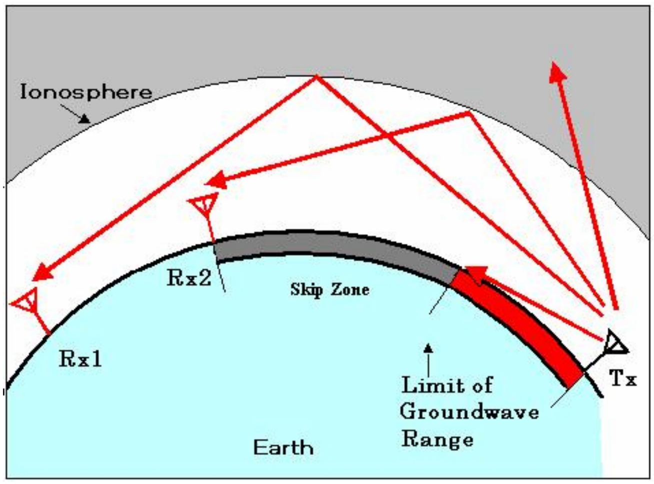

Figure 1 Skip Zone in HF Propagation

NVIS arises in dealing with that skip zone problem in HF communication. NVIS, stands for Near Vertical Incidence Sky wave, refers to a radio propagation mode with a very high radiation angle, approaching or reaching 70-90 degrees (straight up), along with selection of an appropriate frequency below the critical frequency, to establish reliable communications over a radius of 0 – 300 km or so. By transmitting at a very high take-off angle the resulting returned energy returns at a similar angle, without a great deal of attenuation and thus saturates an area of the earth below, providing short-medium range communications without gaps in coverage. The concept is illustrated in Figure 2.

It can be summarized that among the many advantages of NVIS are [2]:

- NVIS covers the area which is normally in the skip zone, normally too far away to receive groundwave signals, but not yet far enough away to receive skywaves reflected from the ionosphere.
- NVIS requires no infrastructure such as repeaters or satellites.
- Pure NVIS propagation is relatively free from fading.
- Antennas optimized for NVIS are usually low.
- Low areas and valleys are no problem for NVIS propagation.
- The path to and from the ionosphere is short and direct, resulting in lower path losses due to factors such as absorption by the D layer.
- NVIS techniques can dramatically reduce noise and interference, resulting in an improved signal/noise ratio.
- With its improved signal/noise ratio and low path loss, NVIS works well with low power

Beside that advantages, NVIS also has some limitations, includes:

- NVIS doesn't work on all HF frequencies. Unfortunately, the frequencies, which are best for NVIS, are the frequencies where atmospheric noise is a problem, antenna lengths are long, and bandwidths are relatively small for digital transmissions.
- Due to differences between daytime and nighttime propagation, a minimum of two different frequencies must be used to ensure reliable around-the-clock communications.

The selection of an optimum frequency for NVIS operation is very important for establishing the links. It depends on many variables, such as time of day, time of year, sunspot activity, type of antenna used, atmospheric noise, and atmospheric absorption. To select a frequency to try, one may use recent experience on the air, trial and error (with some sort of coordination scheme agreed upon in advance), propagation prediction software, near real time propagation chart (available on the Internet) showing current critical frequency, or even just a good educated guess.

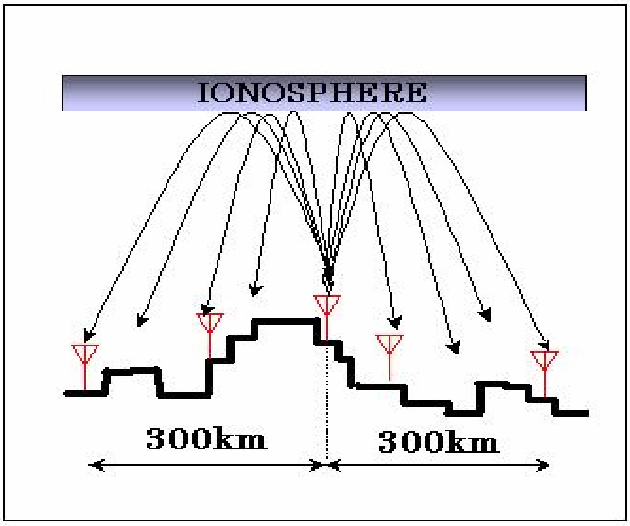

Figure 2 NVIS Propagation

A very rough guide in frequencies selection is to take the higher frequencies (say 6-8 MHz) for daytime working, with the lower (say, 2-4 MHz) for nighttime use, which effectively gives us 40, 80 and 160m. A more accurate method is to follow weekly propagation bulletins or use the several propagation-prediction programs available. A good *'working'* frequency for NVIS will often be between 10 - 15% below, i.e. 85% of the FoF2 Critical Frequency - this is the frequency up to which a return can be obtained from a signal directed vertically at the ionosphere. In practice, to maintain NVIS communications over a 24 hours period, effectively three different frequencies (or bands) are required; a *'day'* frequency (the highest of the 3), a *'night'* frequency (lowest of the 3) and a 'transition' frequency, somewhere between the other two.

After frequencies selection, the next important step is to define the kind of antenna that works well for NVIS. The antenna has to radiate energy vertically. Usually, half-wave dipole antennas located from one-quarter to one-tenth wavelength above the ground will cause the radiated energy to be directed vertically.

3. Performance of NVIS Communication

In other to get insight the usage of digital communication through HF NVIS for disaster medicine, we shall consider the performance. It is mentioned that maximum useful data rate available through a typical HF channel is currently limited to 4.8 kbps (2.4 kbps to be more realistic) [4]. The throughput (actual data rate transfer) usually will not achieve this maximum bit rate. High variation in the channel, especially due to ionosphere, result in variation of critical frequencies and maximum useful frequency (MUF). In this section, we will evaluate this HF NVIS performance, in the sense of throughput efficiency.

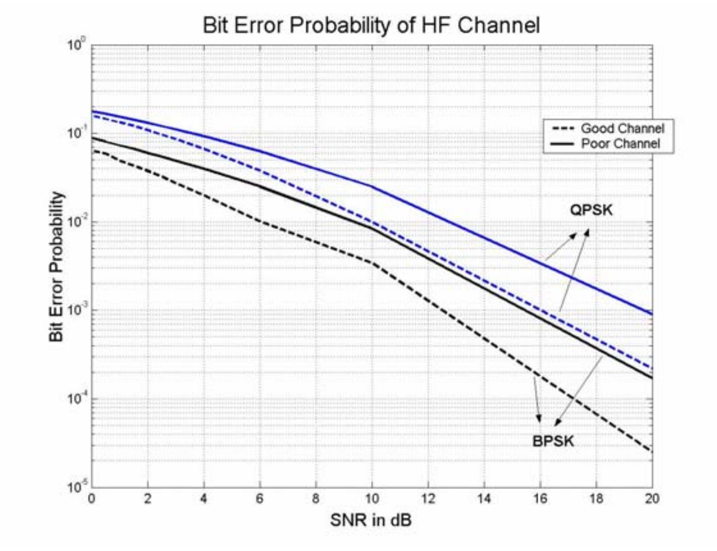

Figure 3 Bit Error Probability Vs SNR for CCIR HF Channel

For performance evaluation by simulation, we shall consider channel model. It was mentioned in the early that for NVIS we can use frequencies between 2-10 MHz. Maximum useful frequency is lower in the night. We can consider best condition and worst condition due to frequency variation into upper bound and lower bound of throughput efficiency. For simulation purpose, it is defined in CCIR Recommendation F.520-2 two types of channel model, Good channel and poor channel, with each has fading frequency spread an multipath delay (Table 1).

Table 1: CCIR HF Channel Parameters

Channel Type	Fading Frequency Spread	Multipath Delay
CCIR Good Channel	0.1 Hz	0.5 ms
CCIR Poor Channel	1.0 Hz	2.0 ms

We consider here that Good Channel is the daytime condition while the Poor channel for nighttime. And while NVIS propagation condition has no dominant LOS signal, we can consider the channel as Rayleigh Fading Channel. Using this channel model, we can simulate the performance NVIS communication system. Figure 3 shows bit error probability versus SNR simulation result for BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying).

Further, from this bit error probability, we can derive packet error probability. This packet error probability is important parameter to find throughput. If bit error probability (BEP) is assumed time invariant, then the packet error probability (PEP) grows exponentially when the sender increase the packet size. From [5] we can calculate packet error probability from bit error probability by formula:
SR ARQ (Selective Repeat Automatic Repeat Request) scheme is considered as effective protocol for error correction, and also used in AX25, protocol for packet data communication which widely used in HF. The throughput of SR ARQ with limited buffer size (actual condition) is defined as [6]:

$$\eta = \frac{1}{1 + (w + \frac{1}{\rho^N} - 1)\rho_0} \qquad (2)$$

$$\rho_0 = \frac{\rho^{N+1}}{1-\rho}$$

where . is *throughput*, w is *window size*, N is (*buffer size/window size*), and is packet error probability.

Suppose setting the parameters by typical TCP/IP-AX25 values, 216 for packet size and 256 for buffer size we get throughput approximation for window size 1024 and 3072 in Figure 4 and Figure 5 respectively.

$$PEP = 1 - (1-BEP)^{(\text{length of packets in bits})} \qquad (1)$$

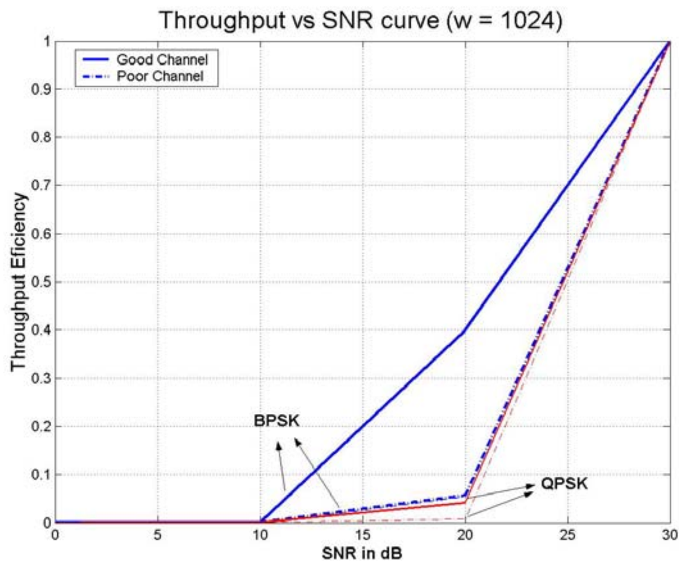

Figure 4 Throughput for Window Size 1024

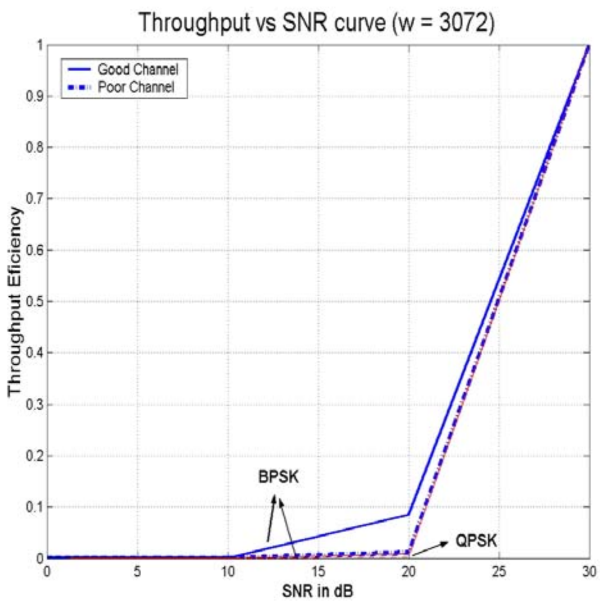

Figure 5 Throughput for Window Size 3072

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4. Discussion

Figure 3 describes simulation result of probability of bit error in HF channel. In this channel, BPSK and QPSK modulated signals will be affected by both additive wide gaussion noise (AWGN) and fading. We can see here that QPSK severe more bit error probability than BPSK in the same SNR (signal to noise ratio). For both QPSK and BPSK, difference between CCIR good channel and bad channel is small in small SNR, and become bigger with the increase of SNR. We can conclude here that for bigger SNR, fading gives more effect than noise. Increasing SNR itself will not take effect to probability of bit error improvement due to this channel condition.

From the figure 4 and 5 we find that throughput for BPSK is higher than QPSK in the same SNR and window size. In the window size 1024, there is big difference of good channel and poor channel in BPSK while in QPSK not so big, for same SNR. This condition also happens in window size 3072 although not so big as before. In the QPSK not so big difference between good channel and poor channel, and for window size 3072 almost no difference.

From the simulation described in section 3, we can see that we need SNR more than 20 dB for all scenarios. This simulation was done by assumption no action taken to deal with fading channel, such as equalization. If we take action to the fading effect, it is hoped that throughput will achieve maximum data rate for typical HF modem such as 1.2 bps and 2.4 bps. Even thought, we can consider HF NVIS for text communication (e-mail), which does not need too high speed data rate. To attain better link continuity, we can use several frequencies under maximum useful frequency (MUF), which fluctuates with time.

In preparing HF NVIS communication, we need several equipments, including PC set and Ethernet card, modem (TNC), HF radio tranceiver, and antenna, as described in figure 6.

To set up the network, it does not need to much expenses. TNC can be built from a kit or purchased assembled for about 150 USD or less, while it needs about 1000 USD for HF radio transceiver set, and antenna can be built with low cost because of easy antenna design (dipole).

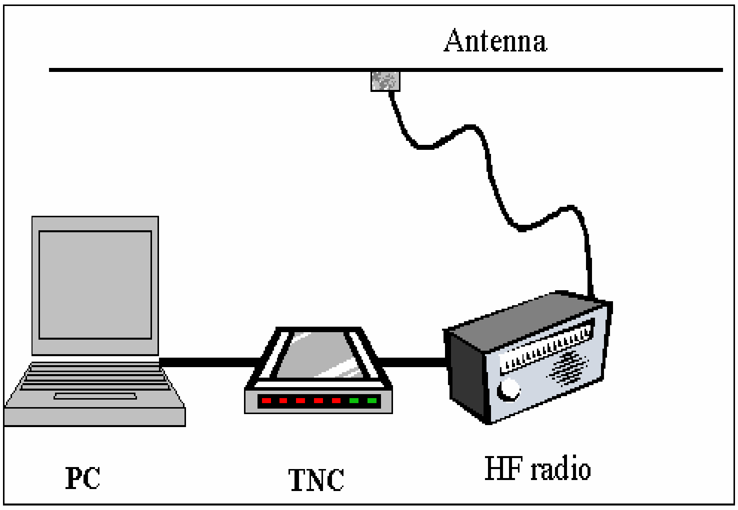

Figure 6 Configuration of HF NVIS Radio Packet Comm.

5. Conclusion

Backup for backbone modern telecommunication network should always be provided to face such unusual condition during disaster, even with the technology, which does not give wide bandwidth and good quality of services. HF NVIS communication seem to be viable solution for distance in the area of skip zone. Throughput performance is enough for text communication. HF NVIS offers low cost and easy to deploy configuration which suitable for emergency and disaster medicine management.

References

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