Null Direction Propagation of Antennas and Counter Measures in Tactical High Frequency Sky Wave Communication

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Abstract: In tactical High Frequency (HF) communication, sky wave and ground wave mode establish the radio link. There is a phenomenon by which antenna in ground wave mode communicates with antenna in sky wave mode. This happens due to emission of radio waves in the NULL direction. This emission can be an unintended transmission, thus can be intercepted and used by the insurgents against armed forces. Also the same can be considered for the friendly communication, thus removing the skip zone. This paper describes the study of Null direction propagation of HF antenna and proposes the counter measures for the same.

Keywords: Null direction propagation, Tactical communication, Mathematical model optimization, Hardware blocking model, Field trial.

1. INTRODUCTION

HF (3-30Mhz) are used for long distance communication and ionosphere is used to achieve the same[1]. The modes used by tactical HF communication are ground waves, space waves and sky waves. We know that ground waves travel for a distance of 40km however sky waves travel for a distance more than 250km[2][3]. It was noticed during a tactical radio link established at the distance of approximately 200km, that the link is having two way communication with one end having rod antenna(uses ground wave mode) and other end having dipole antenna(uses ground wave and sky wave mode). Theoretically same should not function. This depicts some radio waves are emitting in the NULL direction causing the communication to happen which we generally neglect. Thus there is a requirement of managing the same in order to prevent unintended sky wave communication or use it for friendly communication.

Antenna is defined as a piece of material which converts electrical signal into radio waves. These are used for emitting and receiving radio waves in one direction and suppress in other direction so that a directivity can be achieved with an aim to establish wireless communication[1]. Different types of antennas are available for tactical communication which can be mobile, static and of various shapes and sizes. In HF band considerable losses are offered by the ground due to distance and manmade obstacles and electromagnetic propagation characteristics [4][5][6]. Therefore long range can be achieved using ionosphere depending upon power output of the radio set. However the same is unreliable because the height of the ionosphere varies with the activity of sun. Thus simplest antenna used in HF is λ/2 dipole having no directive properties. To achieve high directive properties two or more half wave dipole antennas are connected with each other to form an array.

Various parameters which affect the antenna’s performance over a particular range of frequency are frequency band of operations, polarization, input impedance, radiation pattern, gain and efficiency.

Radiation pattern is known as electromagnetic power distribution in the space. They are representative of relative field strength of field radiated by the antenna. The field are measured in the Θ and Φ direction as shown below in figure 1[7].
Antenna not only radiates power in one direction but also emits energy in the other direction with lower level than the main direction. Thus main direction is main lobe and other directions are side lobes.[8][9].

The radiation pattern also shows NULL in the direction of the ends of antenna[10]. The NULL is the zone having effective radiated power minimum and narrow directivity compared to the main lobe. The power of this NULL lobe is considered to be negligible as compared to the main lobe[11]. This low value of power output in NULL direction compels user to ignore the power transmitted in this direction and concentrate in the direction of main lobe. The power transmitted in this direction is however strong enough to achieve the sky wave communication[11][12]. Thus there is the unintended emission of radiations in the direction which is not known to the user.

2. MOTIVATION
NULL is the direction where emissions of radiations are theoretically considered as negligible. However they are emitted in such a manner that it achieves ranges nearly as achieved in sky wave mode. As these radiations are emitted unintentionally, they also lead to loss of information especially if used by armed forces in unclassified mode. Direction arrival technique available can estimate the direction of transmitted wave, thus location of the armed forces emitting the same can be tracked[13][14]. The interception of these waves in the terrorism affected areas may lead to a greater security threat. Thus above factors motivated to study the NULL propagation of radiations and suggest countermeasures in order to prevent the unintentional emission of radiations in the direction.

This paper focuses on hardware blocking the unintended emission of radiations in the sky wave direction, thereby making the transmissions secure. If these transmissions are not controlled, this becomes a security hazard. The results will help the users in ground wave mode to avoid the unintended transmission of various rod/whip antennas. Also if this phenomenon is not unintentional then it can be utilized to achieve long ranges without any skip zone or skip distance in between two radio stations.

The radio waves travel between transmitter and receiver over two main paths i.e. ground waves and sky waves. Sky-wave propagation uses ionosphere for signal path between the two antennas. When a radio wave is transmitted via ionized layer refraction and bending of waves occurs. Parameter which defines this refraction of waves depends on density of ionization, frequency and angle of insertion of wave.

Long distance HF phenomenon is dependent on ionosphere and its generation. The less number of sunspots and less plagues generates less extreme Ultra-voilet (EUV) and X-rays, thereby reducing the Earth ionosphere thus results in poor long distance communication. These EUV and X-ray energy originates from bright active areas in the Sun’s Chromosphere called plagues and are formed before the sunspot appears and disappear after it. EUV and X-ray energy is responsible for the formation of Ionosphere. As the sunspots increases on the Sun, large numbers of plagues radiating vast amounts of EUV and X-ray energy, creating denser upper Ionosphere, thus enhancing the range for long distance HF communication[15][16].

3. OBJECTIVES
This paper studies NULL direction radiation pattern of HF antenna, its blocking and countermeasures in HF sky wave communication. The objective of the study focuses on:

a. Study of radiation pattern of various antennas like rod, whip and dipole in both ground wave and sky wave mode.

b. Study of various ionospheric charts.

c. Study of variables affecting the radiations in the NULL direction and proposing a mathematical model.
d. Study of effect of various material on antennas and radiation pattern[17].
e. Selection of various software for simulation of radiation patterns for various frequency, power output, material types and shapes[18][19].
f. Field trial to verify the results.

4. METHODOLOGY

In order to propose new system there is requirement of obtaining the ranges achieved by the various antennas so that a methodology can be proposed to stop the unintended spillover of the radiations. The ranges achieved from the various antennas are shown in Table 1.

Table 1: Communication ranges achieved from antennas

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Type of Antennas</th>
<th>Mode of Communication</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dipole - Rod</td>
<td>Skywave-groundwave</td>
<td>200 km</td>
</tr>
<tr>
<td>2.</td>
<td>Dipole - Dipole</td>
<td>Skywave-skywave</td>
<td>400 km</td>
</tr>
<tr>
<td>3.</td>
<td>Rod - Rod</td>
<td>Groundwave-groundwave</td>
<td>40 km</td>
</tr>
<tr>
<td>4.</td>
<td>Whip - Whip</td>
<td>Groundwave-groundwave</td>
<td>35 km</td>
</tr>
</tbody>
</table>

This table depicts various types of antennas, their communication ranges and mode of communication. It is observed that when two antennas are communicating with each other in skywave mode due to ionospheric effect, long ranges are achieved. However when we use antennas in groundwave mode, there is no role of ionosphere, thus short range communication is achieved. It was noticed when two antennas communicate to each other in groundwave and skywave mode, due to ionospheric effect, long range communication can be established. This establishment of long distance communication leads to study of NULL direction.

After studying the ranges achieved from various antennas, the study will commence with the analysis of radiation patterns of various antennas to include rod, whip and dipole. The special emphasis will be laid in the NULL direction and result will be obtained using different frequencies, power output and at different distances from the antenna end. The study of the radiation pattern will be carried out on the above mentioned antennas in both ground wave and sky wave mode. The phase characteristics study is essential and will be studied in designing of antenna[7].

The ionosphere plays an important role in sky wave communication. Thus there is a requirement to study, understand and analyze the ionospheric charts so that effect of ionosphere on long distance communication can be appreciated and understood[15][16].

The antenna radiation pattern cannot be analyzed properly until they are simulated using antenna simulation software. Thus there is a requirement of selecting suitable antenna radiation simulation software which gives the results of various antennas in different frequency, different power output and different ground conditions. The same should also be able to select various segments of antenna in order to feed antenna and display patterns in both 2d-dimensional and 3d-dimensional domain.

Simulation results for the mathematical model may obtained for the optimal values of null blocking efficiency[20][21]. The use of various type of material and their effect on various radiation patterns may be considered while assimilating the results[17].

The simulation results achieved through the above procedure may be analyzed through the field trials. Two teams comprising of radio sets and antennas (sky wave mode and ground wave mode) i.e. dipole and rod antenna may be placed. One detachment will be grounded at a particular location with both antennas i.e. dipole and rod. Other detachment will move with its accessories and take readings at the specified locations in the direction of fire for different frequencies and power output.
The methodology of proposed work is shown in work flow diagram as per figure 2.

![Flowchart](null)

**Figure 2: Methodology of work**

Various materials are used for preparation of antenna and they show various effects over the radiation pattern. Depending upon the material used the conductivity of the antenna and their radiation emission increases or decreases. The hardware blocking model which will be proposed after the results will be designed to have maximum effects on the NULL direction and have minimum effect on the radiations emitting in the main lobe. The shape and position of the block will help to control the radiations. The block can be in various shapes and placed at various locations in the antenna such that NULL radiation can be emitted.

5. **UTILITY**

The study will have double advantages. First the radio transmission using ground wave communication will have sky wave component thereby increase the range of transmission with same power transmission. Secondly this study will assist in securing radio communication without using a secrecy device thereby maintaining the range and avoid spill over in undesired direction[22].

6. **CONCLUSION**

The study of NULL radiation of antenna will help in eliminating the unintentional emission of radiation and also prevent loss of information especially to the security forces. The study may result in eliminating the skip zone thereby increasing the range of tactical communication over HF thus help in enhancing the range and reducing the effects of NULL radiation.

**REFERENCES**


