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The Study of electromagnetic pulses propagation process and the calculation of received power at different heights caused by electromagnetic bomb

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ABSTRACT

In this paper, along with the study of the propagation of strong electromagnetic pulses caused by electromagnetic bombs, in the atmosphere, the received power at the ground surface caused by an electromagnetic bomb has been calculated with power of 10GW at height of 5km. To this calculation, the distance between the location of the explosion to the ground has been divided into several layers (three and four). Equations of reflection and waves passing through different layers solved by numerical method, and finally achieved the reflection coefficients and passing through the last layer. Based on the results, the amount of received power by the ground surface for propagation angle of 5 degrees is 2/1 GW. With this value strategies for reducing vulnerability against electromagnetic pulses can be designed for vulnerable devices with much more precise. The method used in this paper can be used for the calculation of different heights, different power and different propagation angles.

Keywords - electromagnetic bomb, electromagnetic waves, waves propagation, atmosphere

I. INTRODUCTION

The strong pulses in the spectral region of microwave waves with frequency range 100MHz to 10MHz are produced on the electromagnetic bomb explosion. Generally, their power is in the range 100MW to 100GW. These bombs, generally, are exploded at heights of 5km to 10km from ground surface [1]. Electromagnetic bomb is a weapon which uses of human deep dependence to electricity. Weak electromagnetic pulse disrupts the electronic systems temporarily, strong pulse destroys computer data and very strong pulse disables all electronic and electrical systems. The permeability rate is a function of the intensity of electromagnetic field and the way of target covering. The effect of these waves on electronic components varies from one component to another component according to the factors such as time, pulse width, drop time and sensitivity level of component. Advanced electronic equipments are more sensitive against these waves and they are more impressionable [2]. The destructive radius of these waves is 300 to 500 meters. Placing systems and equipments inside a metal case that is known as Faraday cage is one of the effective methods for their protection against damaging effects of electromagnetic [3]. This case could block the vulnerability significantly if designed properly. It goes without saying that the most important factor for designing a Faraday cage is the calculation of power level which reaches the ground surface after electromagnetic bomb explosion [4 & 5]. In this paper, the calculations results for bomb explosion have obtained with power of 10GW at height of 5km from ground surface. This height has been divided into several layers, reflection equations and waves passing through them solved by numerical method. The amount of received power by the ground surface has been calculated by propagation angle and reflection equations and passing through the last layer (the layer near the ground). As we know, magnetic waves are released cone-shaped in space, the apex angle of the cone is called propagation angle.

II. THEORY

Troposphere is the lowest layer of atmosphere. Usually, the layer thickness is from 17 to 18 km at the equator, 10 to 11 km in temperate regions and 7 to 8 km in the poles (Figure 1).

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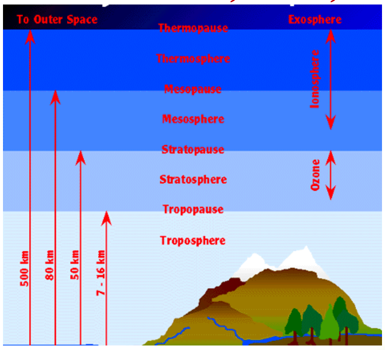

Fig 1. The height of different layers of atmosphere

Space waves are undergoing of absorption, reflection, refraction and dispersion through the troposphere and the obstacles in the path. The calculations have been done regardless dispersion. Atmospheric refraction on the ground surface and in temperate climate is approximately 1/000340 and is a function of temperature, pressure and humidity [6]. Atmospheric refraction can be calculated by presented experimental values in references, or measured with a gauge failure directly. Refraction (n) can be obtained from the following formula [6],

$$n = (77.6(\frac{P}{T}) + 3.75\times 10^{5}(\frac{e}{T^{2}}) - \frac{5.6}{T}e)\times 10^{-6} + 1 \qquad (1)$$

which T is absolute temperature on the Kelvin, p and e are atmospheric pressure and water vapor pressure on Mbar respectively. The ability of radio failure decreases with increasing height from ground surface. If the waves released on the ground from height of 5 km and destructive radius of these waves was 500 m, this height could be divided into different layers and each layer could be a dielectric [7] and calculated reflection coefficient and passing through layers. Since the electric and magnetic field at the interface is the sum of all input and output fields which are represented by positive and negative respectively, therefore for electric and magnetic fields at the interface between layers m-1 and can be written: [8]

$$\vec{H}_m = \mu_m(\vec{E}_m^{+} - \vec{E}_m^{-})$$

$$\vec{E}_m = \vec{E}_m^{+} + \vec{E}_m^{-}$$

$$\vec{E}_{m-1}^{+} = \frac{1}{t_m}\left[E_m^{+}\exp(i\partial_m) + r_m E_m^{-}\exp(-i\partial_m)\right] \qquad (2)$$

$$\vec{E}_{m-1}^{-} = \frac{1}{t_m}\left[E_m^{-}\exp(-i\partial_m) + r_m E_m^{+}\exp(i\partial_m)\right] \qquad (3)$$

The rewriting result of these equations as a matrix is:

$$\begin{bmatrix} E_{m-1} \\ H_{m-1} \end{bmatrix} = \begin{bmatrix} \cos(\partial_m) & {}^{i}/_{\mu_m}\sin(\partial_m) \\ i\mu_m\sin(\partial_m) & \cos(\partial_m) \end{bmatrix} \begin{bmatrix} E_m \\ H_m \end{bmatrix} \qquad (4)$$

As seen, characteristics of successive layers can be related to each other and in this way we will be able to generalize the matrix method for many successive layers:

$$\begin{bmatrix} E0 \\ H0 \end{bmatrix} = M_1M_2M_3......M_m \begin{bmatrix} E_N \\ H_N \end{bmatrix} = \prod_{m=1}^{N} M_m \begin{bmatrix} E_N \\ H_N \end{bmatrix} = \prod_{m=1}^{N} M_m \begin{bmatrix} 1 \\ \mu_N \end{bmatrix} E_N \qquad (5)$$

$$M_m = \begin{bmatrix} COS(\delta_m) & \frac{i}{\mu_m}\sin(\delta_m) \\ i\sin(\delta m)\mu_m & COS(\delta_m) \end{bmatrix} \qquad (6)$$

$$\delta_m = \frac{2\pi \ n_m \ d_m \ COS(\vartheta_m)}{\lambda} \qquad (7)$$

$$\mu_m = \sqrt{\frac{\varepsilon_0}{\mu_0}} \ n_m COS(\vartheta_m) \qquad (8)$$

Matrix Mm is known as specific matrix of M layer. The propagation angle is obtained on height by destruction radius and the propagation height of these waves.

III. RESULTS AND DISCUSSIONS

If we considered the propagation height of these waves from 5km of the ground, troposphere layer, we could divide the height into different layers. For simplicity, we have done the calculations in this paper for three and four layers without decreasing overall results. Refraction of each layer has been calculated by equation (1). The amount of E_0 and H_0 is calculated by the following equations:

$$E_0 = \left({}^{2S_0}/_{c\varepsilon_0}\right)^{1/2} \qquad (9)$$

$$H_0 = \frac{S_0}{E_0} \qquad (10)$$

Then the amount of reached E and H to the ground surface is calculated by the equations (4) to (7). S_0, H_0 and E_0 are the amount of primary power, primary magnetic intensity ($B_0=\mu_0H_0$) and primary electric field respectively and the amount of received power by the ground surface has been calculated by:

$$S = E\times H \qquad (11)$$

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In figure (2), the curve of received power at different heights has been used for three layers. The received power at the ground surface is 4 GW.

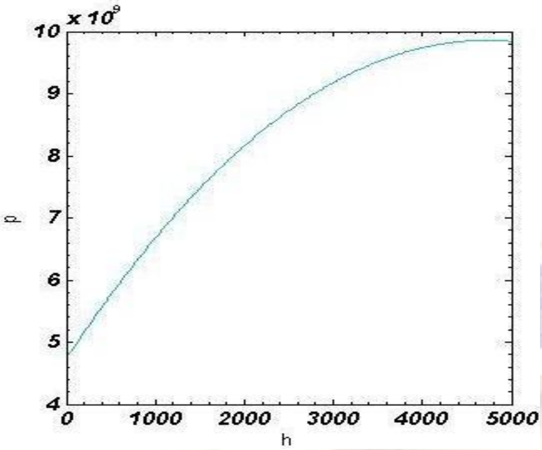

Fig 2. The diagram of height on received power (three layers) (launch height, 5km; bomb power, 10GW; destruction radius, 500m)

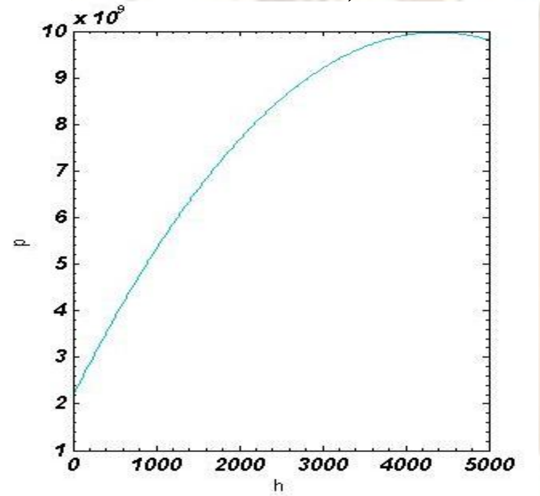

Fig 3. The curve of received power on the received power (four layers) (launch height, 5km; bomb power, 10GW; destruction radius, 500m)

In figure (3), the curve of received power on height has been used for four layers. The received power at the ground surface is 2/1 GW. It goes without saying that, the results are somewhat different, but the general shape of curves 2 and 3 are similar to each other. Totally, results of the four layers are closer to reality. Therefore, if the number of layers is more, more realistic results are obtained which are match with experimental results. Choosing layers depends on detailed information of data needed for the different layers. So, we should prepare an appropriate data bank for our country in order to do more accurate calculations.

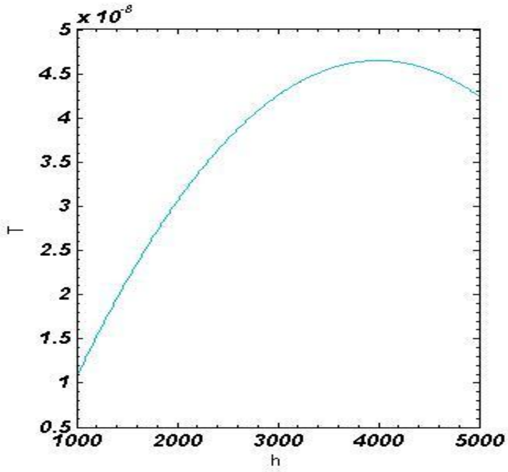

Fig 4. The curve of transfer coefficient based on the height (4 layers) (height, 5km; power, 10 GW)

In figure (4), the curve of transfer coefficient has been drawn based on received power. As seen, the amount of power transfer at the height of 4 km is the maximum. In figure (5), the curve of received power at the ground surface is based on propagation angle. It can be seen that received power has a fluctuated relation with propagation angle and is the maximum in angle of 5 degrees.

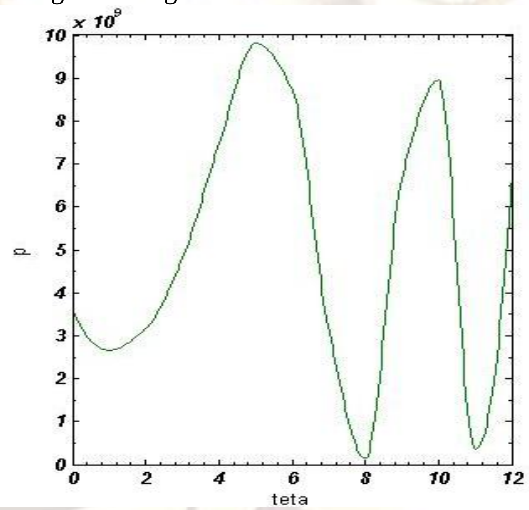

Fig 5. received power at ground surface based on propagation angle (4 layers) (the height, 5km; power, 10 GW)

IV. CONCLUSIONS

It can be obtained an appropriate model in order to calculate the amount of received power in different layers with specific height, for a specific released power of an electromagnetic bomb explosion and using appropriate experimental data for every geographical region. The results of model for the height of 5km and power of 10GW shows that the optimum propagation angle is 5 degrees and the received power to ground is 2/1 GW. The received power to the ground can be calculated easily by curve of 3. The fluctuated received power to the ground shows the importance of propagation angle which drawn in figure 5. In model, if the number of layers is more, the amount of received power in different layers is more precise. In the presented method of this paper, different powers, various heights and different propagation angles can be used for explosion which is a unique feature.

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