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THE CONCEPTION OF A COMPUTER FOR HEIGHT COMPUTATION ON TELECOMMUNICATION ANTENNAS

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Abstract: *Telecommunication antennas are the main constructive and technological components for accurate transmitting of emission – reception signal. The construction and the sizing are essential elements for a high quality transmission. The presented computer in this paper permits the computation of height for telecommunication antennas that are located between two main stations in order to obtain a direct visualization line which avoid the obstacles. The computer takes into consideration the following: emission frequency, earth curvature (radius), distance between earth and the obstacle, the so called Fresnel zone and the refraction effects in the atmosphere. Solutions for antennas with same height and with different heights with natural obstacles between stations of different heights are presented. It is possible to compute the height of telecommunication antennas on a direct visualization line taking into account refraction effects in atmosphere.*

Keywords: *telecommunication antennas, computer, Fresnel zone, refraction*

1. INTRODUCTION

Telecommunications antennas (TC) are the main constructive and technological components used for accurate transmitting of emission – reception signal.

The category of tower-shaped buildings and pillars includes: radio and television towers, radio masts, lighthouses, some high towers, chimneys, towers of power transmission lines and more.

Tower-shaped buildings are usually embedded in the foundations. Pillars are related to building foundation and articulated with cables anchored at different heights.

Towers and pillars were the spatial compositions, lattice or solid cylindrical shape of their surfaces, made of thin sheet metal. Cross section can be square, triangular or round. Construction and dimensions of height to cross is very high. The vertical section in construction can be vertical or slightly inclined with some curvature, vertical section widening towards the base.

2. THE CONCEPT OF RADIO TRANSMISSION [1]

To send information between the subscriber and the mobile network using a radio channel anyone who has traveled by car while listening to a radio show, noted how the quality of reception changes over time (or tunnel crossings between two hills, etc.).

This effect is called "shadowing" or long-term fading, and is the main problem of radio communications.

Knowing the reaction channel of communication (radio channel) it is important to choose those methods of modulation or coding, the base station antenna parameters (position, height, type) so that communication be of a good quality.

Due to natural barriers (landforms, vegetation, etc.), and because of relatively low construction height, the antenna dish are rarely direct vision, in other words, rarely, there is a direct propagation path (LoS - Line of Sight).

Such a channel BTS - MS except of the free space propagation (direct spread) several ways of propagation (along with moving furniture) is known. These paths are the result of the phenomena of reflection, diffraction or scattering radio waves (Fig. 1).

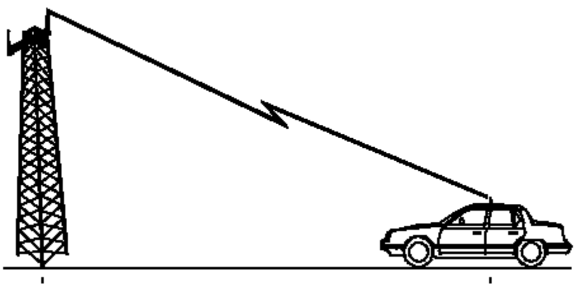

Fig. 1. Propagation in free space

Reflection occurs when an electromagnetic wave encounters a barrier much larger than the wavelength, resulting from reflection on the surface of the earth where the mobile (MS) with it constructively or destructively interfere.

Diffraction occurs when the antenna between the transmitter and receiver structure interposes an impenetrable mass and electromagnetic (hill, mountain, large building, etc.), however, behind it is finding a radio-frequency electromagnetic field. This is explained by the phenomenon of diffraction, which is based on the appearance of secondary electromagnetic waves.

Diffraction is one of the mechanisms that explain the possibility of communications between buildings in urban and rural areas where is no LOS propagation.

Scattering occurs when in the direction of propagation there are objects with dimensions similar to the wavelength of radiation.

When a mobile wave moves within an area covered by electromagnetic field three propagation mechanisms influence the amount of received signals differently depending on the geographic and architectural configuration. An important aspect in the analysis of the radio signal is spread in existence or not of direct visibility (LOS). We can say that in large cities practically propagation takes place without the existence of LOS paths.

Weak signals is an important issue, they can be interfered by the signals (Fig. 2) strong undesirable working on the same channel as the desired signal. Therefore, the cellular system with frequency reuse, interference may occur if special precautions are taken. A special measure taken in this context refers to the alteration of the output power BTS and MS on the downside, if the distance between them is small enough to enable optimal communication with lower emission power.

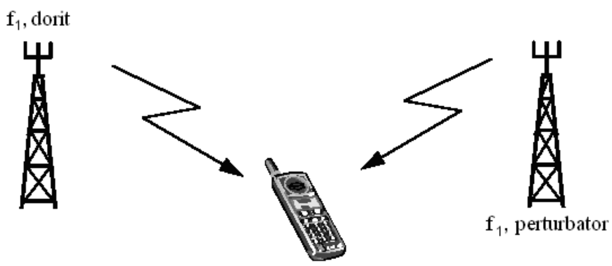

Fig. 2. Interference signals

Obstacles between cell base stations creates a shadow effect which decreases the received signal strength. When the station moves, depending on signal strength fluctuates between obstacles between the transmitting antenna - and receiving antenna Tx - Rx (there is an incoming signal fading or fluctuation).

Fading is a variation of signal intensity:

- Long-term fading (shadowing) (Fig. 3) is amended due to the shape of the land along the route of spread - fluctuations are slow.
- Short-term fading or Rayleigh fading (Fig.4), is due to waves arriving from the immediate vicinity of the mobile structures (structures within a distance less than 100λ are rapid fluctuations. In the latter case, it decreases to reach - 20dB (100 times) or even-30dB (1000 times) in some situations.

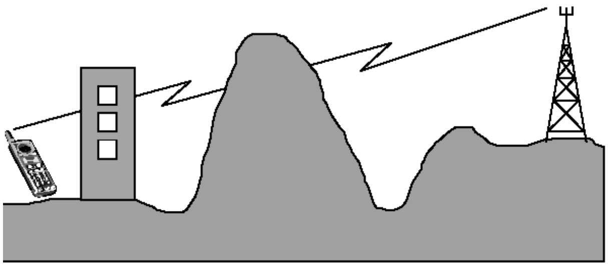

Fig. 3. Long-term Fading

Rayleigh fading (Fig. 4) occurs when the signal between two antennas passes through more than one way. In this case the signal is not received directly from the transmitting antenna. Moreover, he bounces (of buildings, for example) and is received in several different ways.

In this case, the signal is a sum of several identical signals which differ only in phase, resulting in a final signal which has the maximum and minimum envelope. Minimum time between two mobile stations depends on the speed and frequency of the radio channel.

It should be noted that the terms associated with fast and slow fading is an inappropriate choice by the fact that fading is a spatial phenomenon and not temporary. Justification is found in the fact that spatial variations are collected by a moving vehicle that changes position in time.

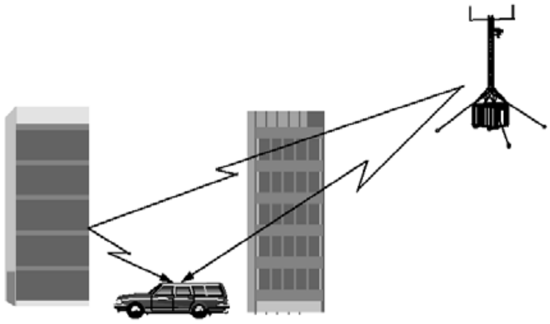

Fig. 4. Rayleigh fading

Time dispersion (Fig. 5) is another problem exists in digital broadcasts, which although it has its origins in reflections, is in contrast to multipath fading, as reflected signal arrives at an mobile object at big distance from the receiving antenna (Rx).

Propagation time dispersion due to interference between symbols (Inter-Symbol Interference) where consecutive symbols interfere with each other making the difficult task of their correct interpretation by the receiver.

The figure below sequence 1, 0 is issued by the base station and the reflected signal arrives a bit later than during the direct signal, the receiver detecting a symbol of the wave reflected at the same time as the symbol 0 from direct light. The symbol 1 interferes with the symbol 0.

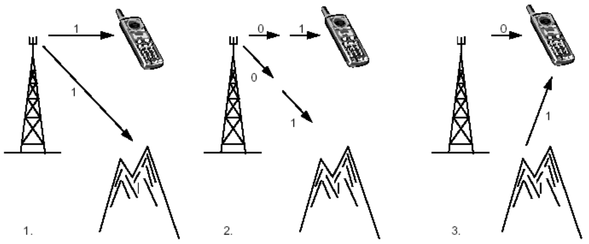

Fig. 5. Dispersion time

In the GSM radio channel transmission rate is 270Kb/s, which means that the length of a bit is 3.7 ms. So, a bit corresponds to 1.1 km, and if there is a 1 km reflexion from behind the mobile station, the signal is reflected by the Route 2 Km. In this case, mixing occurs between two direct and reflected signals, causing errors on the radio path. Their compensation is made through specific means.

Outdoor areas of a GSM coverage is assumed to be sufficient if the power received by a mobile is less than the amount projected to be around-90dBm (1 pW) over an area of 95% of total.

Indoor coverage is the percentage of the ground floors of all buildings in the area where the GSM signal strength is above the required signal of furniture, which is fixed at-97dBm.

Losses due to penetration of buildings are defined as the difference between the signal strength outside the immediate vicinity of the existing building and the signal strength on the ground floor.

3. Radio line viewing

At the microwave frequencies when performing an RF link between two remote sites that must exist between the two antennas to a line of view. But at these frequencies is not just the line of view from a site that you can see the other. When such distances exceeding eight miles, must take into account the following factors [4]:

- The curvature of the Earth;
- Distance from ground / obstacle Fresnel zone;
- Atmospheric refraction.

a. *Earth Curvature*

Figure 6 illustrates these concepts with an exaggerated representation of a long link.

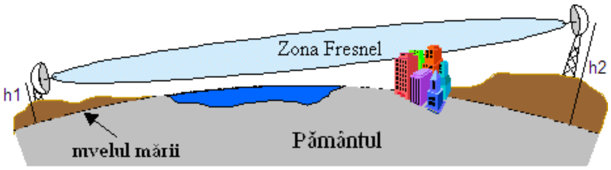

Fig. 6 Fresnel Zone with obstacle

Fresnel Zone (Fig. 7) is a long ellipsoid that lies between two antennas. The first Fresnel zone is such that the difference between the direct path (AB in the figure below) and an indirect way to achieve a single point on the edge of Fresnel zone (ABC) is half the wavelength.

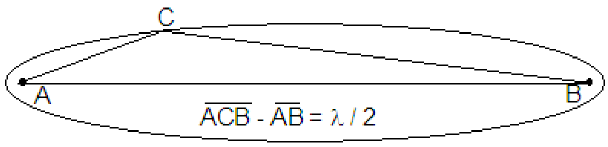

Fig. 7 Fresnel Zone

If a significant portion of the Fresnel zone is blocked, the signal reception can be greatly attenuated. In general it is necessary that at least 60% of first Fresnel zone is clear of obstacles for the propagation of radio wave to behave as would be in free space. 60% of first Fresnel zone is an ellipsoid with a narrower range that is 60% of the radius of the first Fresnel zone.

Even if half of the 2.4 GHz wavelength is only 6.2 cm long distances can be very large ellipsoidal radius. For example, a link distance of 50 km radius of the ellipsoid (60%) in the middle section is 23 m. The calculator can be used to calculate the radius at any point between two antennas. You can also change the percentage of the first Fresnel zone.

Fresnel zones (Fig. 8) uses a serial number corresponding to the number of multiples of half wavelength, the difference of the radio wave propagation path from the path direct. The first Fresnel zone is thus an ellipsoid whose surface corresponds to a path difference of half wavelength and is the smallest volume of all other Fresnel zone [1].

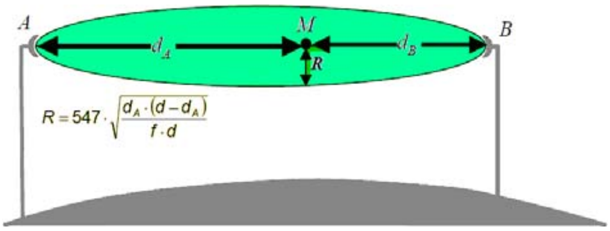

Fig. 8. Fresnel Zone between the two stations located on a surface equivalent of the earth (beam is right).
d_A = Distance from antenna to point M, km
d_B = Distance from antenna B to point M, km
d_A+d_B = d = distance between antennas A and B, km
R = radius of Fresnel zone at point M, m
f = frequency, MHz

b. *Distance from ground / obstacle*

Refractive properties of the atmosphere are not constant. Variations in atmospheric refractive index (expressed by the radius of the earth - the factor k) can force land irregularities to intercept all or part of Fresnel zone. Distance to the obstacle from the line of view (Fig. 9) can be described as a criterion to ensure that sufficient antenna heights, so that in the worst case of refraction (the factor k is minimal), the receiving antenna is located in the region of diffraction.

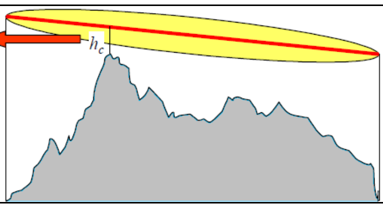

Fig. 9. Distance between barrier to the viewing line

Direct path between sender and receiver must have a distance from the ground or any obstacle to the line of view at least 60% of the Fresnel zone radius to ensure propagation in free space. Distances from the ground / obstacle must match local climatic conditions.

Small values of k down the line view (requires higher antenna heights) but offers better protection from interference from other antennas. Higher values of k give a high-line viewing (requires smaller antennas heights) but expose the link to interference from other antennas.

c. *Atmospheric refraction*

In normal weather conditions, radio waves do not propagate in a straight line, having a slightly downward slope. This is due to atmospheric refraction affecting the radio waves propagate horizontally. To consider this bending downward, all calculations are performed using a higher route to Earth's radius, so that radio waves can be considered as having straight line propagation.

The computer can simulate the Fresnel zone, can change the Earth range multiplication factor (k factor) and take into account the different atmospheric conditions. Under normal conditions, the factor "k" is 4/3. However, unusual weather conditions can cause about significant changes in the refractive profile. For greater certainty of the link using a lower value of factor k[3].

Solution for equal antenna height

For any given distance, the computer displays the Fresnel zone antenna height (same on both ends) so that the Fresnel zone (Fig. 10) just wipe the surface of Earth as shown in the figure below.

Different antenna heights

It is unusual for both antennas to be the same height, so that the computer allows the addition of various heights for the two end points (all heights are above sea level, h1 and h2 in the figure above).

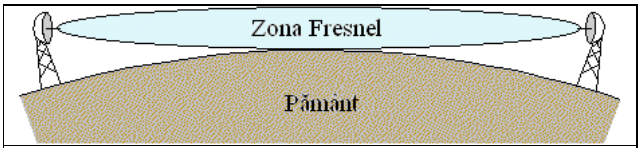

Fig. 10. Fresnel Zone – earth curvature

The computer calculates the path that is the point where Fresnel zone is closest to earth at sea level. It displays both a distance from the site and the distance between the earth at sea level and the lower limit of Fresnel zone. A negative distance means that the Fresnel zone overlaps with the profile of the Earth.

Avoiding an obstacle

The computer determines whether there is enough space above an RF obstacle, or alternatively, how high should be erected antennas to avoid the obstacle. The software need to know each potential obstacle on the path and the distance from one of endpoints and obstacle height above sea level. Draw the path in "Google Earth" is a quick way to identify buildings or structures that are the direct route and find their distances from the points of the head. You may need to use topographic maps, drawing a line between the points of the head and create a profile just on the land. If there are buildings or trees on the track, it is necessary to determine or estimate their height above ground height to be added to the land of those points.

For each of these points of potential obstruction, is calculated place and distance from the site of an obstacle height above sea level in the bottom left of your computer. On the right side of the computer it displays vertical separation barrier between the top and bottom of the Fresnel zone. If this value is negative, it can increase the height of one or both antennas to the distance ground / obstacle is greater than zero.

If more than 60% of first Fresnel zone is free of any obstacle, then spread the RF link will be similar to that of free space.

4. CALCULATOR FOR DETERMINING THE ANTENNA HEIGHT[2]

The computer designed in the paper enables the computations of the heights of telecommunications antennas located between two stations, to get a direct line of view, which avoids an obstacle.

The computing of the Fresnel zone (Fig. 11) and antenna height helps them determine if there is a 'direct line of view "between two distant points, or alternatively, how each antenna to be lifted up to avoid an obstacle. The calculator takes into account the Earth curvature and refraction effects in the atmosphere.

If there is a very long link frequency, these effects must be taken into account.

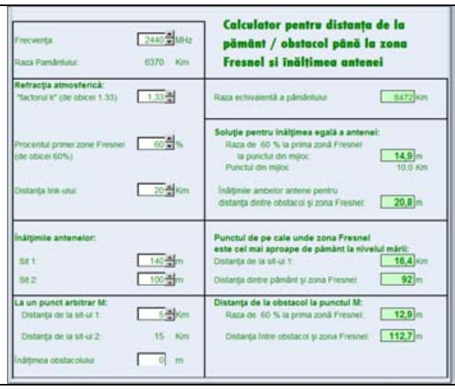

Fig. 11 Antenna height calculator

5. CONCLUSIONS

When calculating coverage of a GSM cell, it should be noted that the power of radio waves decreases with the inverse distance squared (d^2), except that the claim is valid in the empty spaces (the two antennas of the MS and BTS can be seen between them.)

Since stations (MS) are close to earth, we can say with certainty that interference and reflections from the ground cannot be neglected, and the presence of obstacles between the two antennas almost always occurs in crowded spaces. As a consequence, the spread at ground level is more difficult in the urban environments and the received power typically varies with d^{-4}.

Lack of radio frequency (is expensive) put the network designer to re-bind them. The frequencies used in a cell are reused in other cells at distances sufficient that interference is to be eliminated. In reality, this cannot be totally avoided and a cell with interference between radio channels with the same frequency (co-channel interference) and radio channels that have adjacent frequencies between (Adjacent Channel Interference).

The human body, cars and buildings introduce additional attenuation on the radio channel.

The computer designed to assess the antenna height for a direct view between emission and reception points.

6. BIBLIOGRAPHY

[1] Ericsson - RNC Radio Network Features 20/CMS 40 - LZU 108 3704;

[2] Rosca, R.C. *Telecommunication towers and masts*, AGIR Bulletin, 2010;

[3] Saunders, Simon R., Aragón-Zavala, A., *Antennas and propagation for Wireless Communication Systems*, 2nd Edition, John Wiley & Sons, 2007.

[4] Zoican, R., Zoican, S., *Cellular Telecommunications Systems*, Matrix Rom Publishing House, 2003;

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