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Electromagnetic Radiation Exposure of Crowd at GSM Frequencies

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ABSTRACT : *A new type of technology and scientific area has emerged in recent years. It has its own obstactacles and antagonisms while it was intended to utilise its existance and specifications for the benefit of mankind.There are studies, researches and applicaitons on the field heretofore. This study aims to establish an informational, intellectual ground to predict and measure the effects and interaction of electromagnetic wave on living beings present as shoal and RF propagation model for crowd.The crowed ismodelled using discrete method.The body of human modelled as randomly oriented lossy dielectric cylinders of varying lengths and diameters..The distribution andorientation are prescribed.All scatterers are assumed to be distributed uniformly in the azimuth direction.The biophysical input parameters of adult and children to model are obtained from literature childrenThe simulation algorithm was written with different parameters and measurement quantities representing different features(density, dispersion, volume, mass, etc.) of vibrent communities. In order to survey and measure the attenuation of electromagnetic radiation due to flocks of human, the simulation at GSM frequncies is done and presented for horizontal and vertical polarization.*

KEYWORDS **-***Electromagnetic radiation exposure, GSM frequencies*

I. INTRODUCTION

Apart from non-human dynamics and variables, it is now the question that asks how much the human factor affects, by implication is affected by the electromagnetic radiation. There is no need to mention about its biological influence or the obstruction against its spread by objects. However, through a literature survey, we have not encountered an open study about how much human organism as a crowd flock, eliminates, thus reduces electromagnetic radiation flow via absorbation or scattering, or any other way.The presence of crowd along a radio path cause attenuation and results in a reduction of communication range of the radio equipment.

In this study it is aimed to simulate, investigate and demonstrate the attenuation in electromagnetic wave propagation due to crowd and find out whether or how much significance there is,hence to make a conclusive judgement about the issue.Even though there are numbered factors affecting electromagnetic radiation, that is to say, wireless communication, only a single one of them constitutes the focus of the project. If unobstructed, radio waves will travel in a straight line from the transmitter to the receiver. But if there are obstacles near the path, the radio waves reflecting off those objects may arrive out of phase with the signals that travel directly and reduce the power of the received signal. On the other hand, the reflection can enhance the power of the received signal if the reflection and the direct signals arrive in phase.

A realistic model for the propagation of RF throught crowd must consider that there is amore or less random distribution in location,size and orientation of human beings.

II. THEORETICAL BACKGROUND

As an epitome of the article, [1]the suggestion is most basically that the scientific literature has been split into two models on electromagnetic propagation. According to one, it is regarded as a continuous random medium with a postulated average dielectric constant and a fluctuating component which cannot be related directly to the biophysical parameters of the forest. On the other hand, the other proposes that the medium is the sum of discrete elements each characterised by a scattering amplitude. This study uses the second approach for a multicomponents propagation model of crowed where it is modeled as random media.As the propagating RF penetrates deeper into the crowed,the relative contribution of incoherent component becomes more important.

The crowd is considered as an unbounded medium of randomly oriented and positioned homogeneous scatters representing various human.For this case,asimple plane wave solution to the mean-wave equation can be found.EM fields in random media are divided into two sections. One is coherent(mean) fields while the oter one is incoherent(random) fields. Different theoretical approaches exist for different fields. After the assumptions that the identical scatterrers has a volume V_p, a relative dielectric constant ε_r,radius R and a scatter density which is taken as a constant valueρ.The formulized definitions for mean field equation from Maxwell's equations can be obtained by assuming the incident field on each scatterer is in itself the mean field(Foldy approximation). The fractional volume $\delta = \rho V_n$ is very small, e.g, for typical forest it is around 0,1 % which is sparse distribution of scatters[1].

$$E_{pp} = \exp\left(iK_{pp} L\right), p \in \{h, v\} \qquad (1)$$

where the propogation constant K_{pp} is expressed in terms of the forward-scattering amplitude of its individual components as follows

$$K_{pp} = k_0 + \frac{2\pi}{k_0}\{\rho_t f_{pp}^{(t)} \rho_b f_{pp}^{(b)} \rho_n f_{pp}^{(n)} \rho_l f_{pp}^{(l)}\} \quad (2)$$

with $f_{pp}^{(t)}$, $f_{pp}^{(b)}$, $f_{pp}^{(n)}$ and $f_{pp}^{(l)}$ are the average forward scattering amplitudes for trunks, branches, needles, and leaves, respectively.

The specific attenuation for horizontal (h) and vertical (v) polarisation in decibels per metre (dB/m) is obtained as

$$A_{pp} = 8.686\, \mathrm{Im}(K_{pp}) \qquad (3)$$

where $k_0 = \omega\sqrt{\mu_0 \varepsilon_0}$ is the free space propogation constant, L is effective path length travelled by the wave, f is the average (over size and orientation) of the forward scattering amplitude. The scatterersare assumed to be distributed uniformly in the azimuthal direction, and cross-polarised forward scattering amplitudes average out to zero ($f_{pq} = 0, p \neq q$). This unbound medium of discrete scatterers behaves as a continuous, homogeneous anisotropic medium with an effective, dyadic permittivity and propogation coefficient K_{pp}.

As a RF propagates through the crowed,power associated with the mean field is transformed to the incoherent field.Fluctuations of the field about the mean become important when the mean wave decays.On the other hand,the two frequency correlation function is

$$\Gamma(x;\ \omega_1, \omega_2) = < E(x;\ \omega_1) E^*(x; \omega_2) > \qquad (4)$$

can be used to characterise both the mean field and its fluctuations. In eqn.4, E represents the total field which is sum of the incident and scattered fields. Therefore Γ depends on the frequency of the incident wave. If the field is decomposed in to the sum of its mean <E> and its fluctuations about the mean E then the two-frequency correlation function can be written as

$$\Gamma = \Gamma_c + \Gamma_i \qquad (5)$$

where (the mean) coherent and incoherent components of the correlation function

This decomposition of, the correlation function into two parts leads to the view that propagation in a forested environment is composed of a parallel combination of a coherent and an incoherent channel. The antenna excites a coherent wave. After propagating some distance, the coherent wave decays since it is being absorbed through ohmic losses in the trunks and also being scattered into the incoherent wave having random phase fluctuations. The power of the coherent wave is obtained as

$$P_c(x, \omega) = \Gamma_c(x, \omega) = \frac{A_c}{x^2} \exp(-\alpha_c x) \qquad (6)$$

where A_c, α_c are the excitation coefficient and the coherent attenuation constant, respectively. They are given by

$$A_c = \left(\frac{\omega \mu_0}{4\pi}\right)^2 \qquad ,\alpha_c = \rho \sigma_t \ (7)$$

and σ_t is the total crosssection with. The power of the incoherent wave is expressed as

$$P_i(x, \omega) = \Gamma_i(x, \omega) = \frac{A_i}{\sqrt{x^3}} \exp(-\alpha_i x) \qquad (8)$$

where A_i, α_i are the exitation coefficient and the incoherent attenuation constant respectively. They are given by

$$A_i = \sqrt{2\pi W_0 \alpha_c A_c}/\sqrt{\alpha_i},\ \alpha_i = \alpha_c\sqrt{1 - W_0^2} \quad (9)$$

where $W_0 = \sigma_s/\sigma_t$ is the albedo. Here σ_s is the scattering cross-section of the object. The albedo represents the percentage of scattering power over the total power. Since the albedo is always less than unity, eqn. 9 implies that the incoherent attenuation is always less than the coherent attenuation.

While bio-characterising crowed, firstly the basic materials of human,adult, children,white black etc. have similar dielectric properties. Second level is basically geometrical consideration. It involves the depiction of parameters like densities, sizes, and orientations. The third level requires to see human as object with, different part has different dielectric constant.

The human body is the largest part,thus are described in greatest detail. In general the body diameter, probability density function of a (homogeneous) stand or plantation follows the normal (Gaussian) distribution.

2.1 Humanization

There are numerous works conducted in the scientific world, one of which is Camelia Gabriel's Compilation of The Dielectric Properties of Body Tissues at RF and Microwave Frequencies [2-5]. The conclusion of the study is as below.

In biology, trees and humans are seperate different entities, categorised according to the their characteristics. However, even though they are different in many aspects, both are living beings. Therefore a simple analogy can be created between them in terms of their geometrical effect on electromagnetic radiation attenuation. For such a liaison, physical association of the two forms can be as such; trunks of trees can be perceived as human bodies, branches are to become limbs, leaves are similar to extremities(hands and feet), and needles are appropriate match for finger and toes.

Nevertheless, there are some other specifications that requires attention. The geometrical and physical difference between various species and ages of trees are far more significant than the diversity between homo sapiens. The anthropoids have heights between 10 to 90 inches, while this variance is broader for photosentetic organisms. Similarly, the radius of the trunks vary in larger scale than waist widths. Therefore, this case of disparate facts can only be overcomed via simplifications. The difference between different age, mass, size and densities are to be converted accordingly.It is already discovered that human flesh reflects and refrects electromagnetic radiation through absorption and projection. There are studies about cellular effects, micro scale work(on singular human body). However i have not encountered any work about human masses affecting and affected by the radio wave propagation. While searching the topic, this was the very peculiar reason of my enjoyment and enthusiasm. Elimination of side effects of wireless communication, improving the infrastructure and positioning the anthennas accordingly, even turning this science into something useful for humankind are only some of these. Gabriel's findings about human tissues added in Şeker's model, a significant knowledge about the effects of electromagnetic radiation can be achieved. From this perspective, the vegetation in the simulation codes are regarded as antrophomorphic entities(in short, humans are vegetables) with relevant parameters of permittivity, diameter, length, probability, density, and moisture content.

Main contemplation is that there will be a significant effect by cluster of humans on wireless communication. In other words, the scatterring and absorption events affect electromagnetic wave propagation at a considerable level. The proposition saying that humans, in different levels according to their characteristics influence EM wave radiation, indicates that in larger scales trees and humans can be considered as same forms reflecting, refracting, and absorbing. Therefore the prediction for the results of the simulation for the investigation of vegetation should yield similar or meaningfully significant outcomes when the same process is performed for the investigation of hominid factor. Based on the scientific data, propagation models, and formulaic calculations, the parameters diameter(D), length(L), probability(p), density are to be modified accordingly.

III. NUMERICAL SOLUTIONS

The simulation human parameters are implimented.These parameters are firstly determined as made up arbitrary values. Probabilistic values are not changed and remained as vegetational entries. Moisture content is determined from 0.2 to 0.8 with an increase of 0.1 for each simulation. Frequency parameters are determined to be GSM frequencies 00 MHz, 1800 MHz, and 2100 MHz.

3.1 Amelioration

The diameter and length parameters are determined according to the random yet real subject's measurements. The calculations are done according to the measurement calculations in literature [5-8]. Since the permittivity is calculated automatically by the simmulation program according to the moistrure content and frequency values.In other words, there is not a constant dielectric constant even though the values could probably be quite close to each other.

In order to realise this, a sample of random volunteers have been utilized. The heights, the diameters of chest and waist circumferences are measured. Due to the model, these values are converted as height of the cylinder and radius of its crosssection circle. For the L(Length) parameter, the measured height(H) is used. For the D (diameter) parameter, the measured C (Chest Circumference) and W (Waist Circumference) values are summed, then divided by 2π in order to find the diameter of the cylindirical model. The calculation is performed with Microsoft Excel with the following equation.

$$D = \frac{C+W}{2\pi} \tag{10}$$

However, during the survey process some disruptions occurred due to a misconception about waist circumference. The measurement was meant to be done around hipbone. However, the term 'Bel Çevre Uzunluğu' (Turkish translation of Waist Circumference) is the circle circumference just below the navel. The navel (clinically known as the umbilicus, colloquially known as the belly button, or tummy button) is a hollowed or sometimes raised area on the abdomen at the attachment site of the umbilical cord [6-8]) just above where pelvic bone sticks out. In order to eliminate any mismeasurements, the subjects are instructed accordingly.

The table of sample subject parameter values are given below. Peripheries of Chest and Waist (C&W) are used to calculate the diameter (D), and height(H) is directly the value length (L) in cantimeters as the software accepts.

Table 1: The measured height (H for L),

H	155	177	160	171	180	165	178	184	180	198	189	180	165	162	177	181
C	83	95	87	88	104	92	95,5	92	96	116	124	101	105	95	98	95,5
W	71	82	75	82	101	85	103,5	109	96	110	122	87	108	70	96	90
D	24,52	28,18	25,80	27,07	32,64	28,18	31,69	32,01	30,57	35,99	39,17	29,94	33,92	26,27	30,89	29,54

circumference (C), and calculated diameter (D) values of 16 random sample subjects. H& D values are in red indicating that they are the input values of the software.

3.2 Metamorphosis

After the transfiguration of the simulation according to the sample human subjects, the simulation is established properly, and performed for the moisture and at frequency values (900, 1800, 2100). However this once, the frequency range is broadened. In addition, the output value of coherent attenuation is also added to the evalutions. The incoherent attenuation is expected to be more dominant at higher frequencies while the coherent attenuation is more regardable at lower frequencies. The results of the first simulation are plotted below. As it can be observed from the graphs, the vertical polarisation of coherent attenuation is higher than the horisontal polarisation. Whereas, the vertical polarisation of the incoherent attenuation is lower. Meanwhile, it is simply deducable that attenuation in general increas increases with the rise in moisture content.

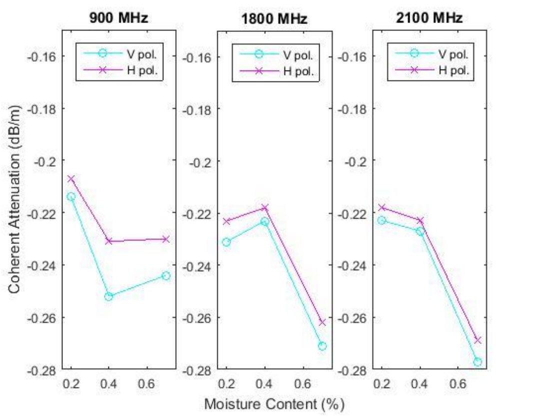

Figure 1. Moisture content vs. coherent attenuation at different frequencies.

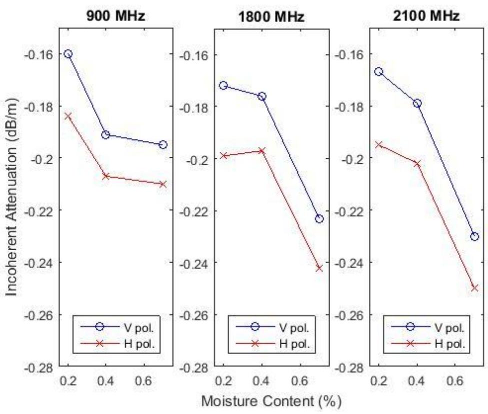

Figure 2. Moisture content vs. incoherent attenuation at different frequencies.

However if it is desired to make a comparison between graphs they do not seem to reflect much information about frequency change. Because by simple observation, we can only say that the frequency increase should also results in attenuation increment. However, it is only apparent at some locations. If the frequency vs. Attenuation graphs are checked, then this situation can be observed clearly in the next figures. Below are the results of the simulations at 0.7 moisture content value for different groups of human subjects at different frquencies. Via the observation of the graphs of different groups, each decrease can be observed clearly. No matter wheather coherent or incoherent, all the graphs reflect that the attenuation is decreasing with the increase at the frequency.

Finally, it would be considerate to check all the graps with coherent and incoherent attenuation values all together. Below is the final graph where the final impications can be understood.

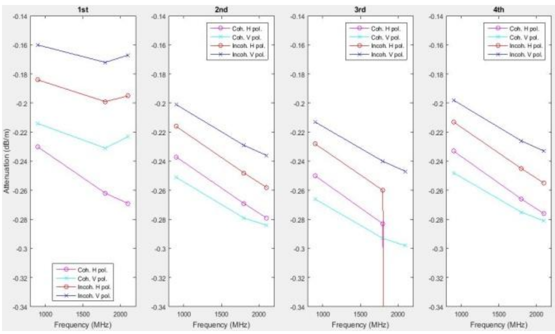

Figure 3: Frequency vs. attenuation for all groups.

It can easily be seen from figures that the general trend of the curves are decrease. The results are graphed below. These are quite similar to the trunk curves. Namely, even though the branches are included, the outcomes are more meaningful. The only difference is that total curves are at decay(attenuation at increase) while the vertical attenuation is at decay with frequency increase(the curves are increasing)

In order to understand this occasion, more data are collected. The 16 human subjects are divided in 4 groups. The first group has the results presented above. Different moisture values may create confusion in understanding the frequency effect directly and weather conditions are not the major goal of the study. Therefore it is frugal to circumscribe around a singular moisture content value. The simulations are run at both levels of 0.2 and 0.7. However, since the values at 0.7 are clearly more reliable, the overall graphs are plotted at that moisture content value. Below are the results of the simulations at 0.2 moisture content value for different groups of human subjects at different frequencies as seen in figures 4 and 5..

The previous graphings were made from total outcome. It is not necessarily mistaken for comparative aims, but they all contained some noise factor. Therefore the output values are reorganised for only trunk values representing human parameter values in order to achieve more correct numerical values. The graphings are made again according to these numerical values and the plots below are achived.

As it can be observed via the plots, the results yield an interesting result for vertical polarization. For all groups and for each type of attenuation, the vertical polarisation curve diverges towards the horisontal polarization curve, which in other words the vertical attenuation increases while the horisontal one increases.

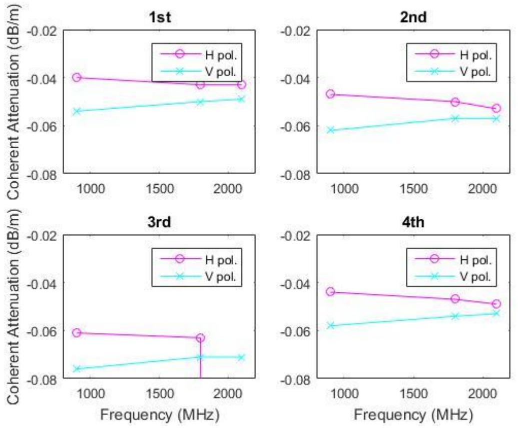

Figure 4. Frequency vs. Coherent attenuation.

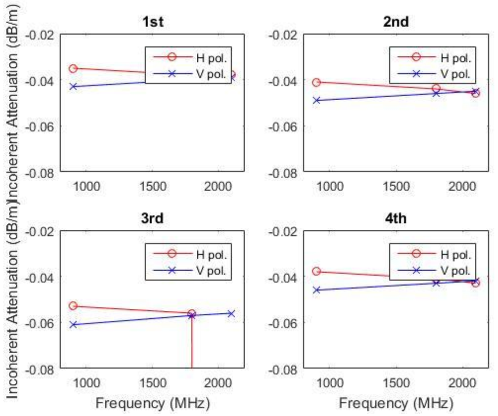

Figure5. Frequency vs. Incoherent attenuation.

After this simplistic approach, various other approaches to crowds are decided to be performed. A combination of babies, children and adult parameters are decided to be inserted as the input parameters. The assumption happened to be that the crowd is a sample population So from a simple example the broader implications could be made.

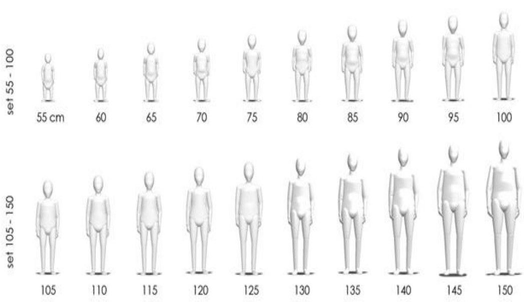

Figure 6. Child height range [6]

Some statistical knowledge was researched simply by the internet and the average ranges are found. These datas are not used directly as how they were, but converted into level values arbitrarily [6-8]. Instead of such an approach, another one could have been done, which is the clone assumption of a single perfect body. Thus, the parameters of Leonardo Da Vinci's Vitruvian Man could be utilised. However, it was concluded to perform the simulation with more realistic inputs rather a direct, perfect calculation, in order to conduct a more life touching experiment.

Therefore the input values are inserted as below. The assumption of analogic approach is as such: The needle is reduced to the values that can be ignored, leaves are converted to babies, branches are happened to be children, and finally trunks are assimilated to adults.

Infant(0-2): 50 - 60 - 70 – 80, Child(3-17): 100 -120 - 140 - 160

Adult(18+): 150 -160 - 170 – 190

Besides the height values, the diameters are also decided arbitrarily with a logical diversion. Below is the input values with new parameters. The left column is the diameter while the right one is the heights.

1.00	10.00
14.00	50.00
15.00	60.00
16.00	70.00
18.00	80.00
20.00	100.00
22.00	120.00
23.00	140.00
24.00	160.00
26.00	150.00
28.00	160.00
30.00	170.00
32.00	190.00

Table 2. New input values.

The simulation was performed for all three frequencies as before. This sample population would have the probabilities of a real statistical data of a set, that is to say the population rates of The Turkish Republic.[7-8] Below in Fig.7 are the outcomes for the three frequencies. (900, 1800, 2100 MHz)

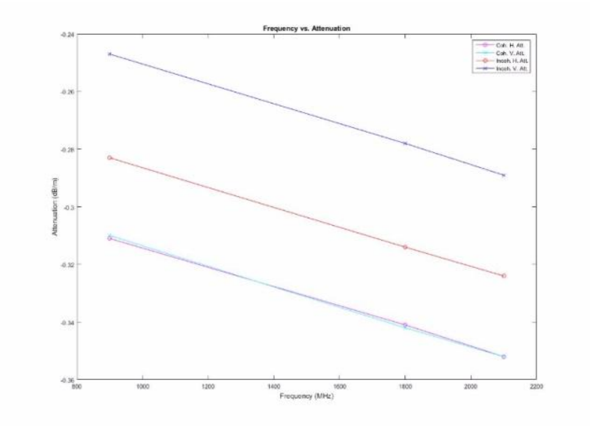

Figure 7. Frequency vs. attenuation.

It can easily be observed from figures that the attenuation stil increases with the frequency increase and the other relative predescribed implications hold. The significant meaning of this simulation becomes then the values of the each block. In order to reach more accurate and realistic results, the probability values as well as the density parameter should be ameliorated.

IV. CONCLUSİON

This study presents a simple and accurate new formulation which is valid all frequencies when the crteria is satisfied of e.m. propagation through crowd.The model can be used to improve the measured results.Singular human effectivity on attenuation is close but curtailed compared to a tree, thus vegetation, especially sylvan environments are slightly more effective than hominid crowds.Incoherent attenuation is less dominant, namely has lower values than coherent attenuation has. The difference seems insignificantly small for relatively small environments and amounts of target subjects, yet, it enlarges with the quantity. Coherent vertical polarisation is higher than coherent horisontal polarisation while incoherent vertical polarisation is lower than incoherent horisontal polarisation.

The variations of target human dimensions have close values and without very large and dense quantities do not result in exalted attenuation value differences. However, larger objects with bigger dimensions have more influence on electromagnetic wave propagation.Any kind of attenuation, or simply attenuation in general, increases with frequency increase. However, this process asks for its practical details. Due to the self made limitations, the project did not contain many aspects that could enrich the contents. Yet the results are sufficient for predictions and prescience. In addition, a change in frequency,volume or dielectric constant just shifts the level of given curves butdoes not change their shape.Their shape only depends on probabilistic distribution function.

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