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A Binomial Approach for Redefining Risk Assessments of Latent Hostile Hazards

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ABSTRACT: *Health and safety risk assessments are constructed on the premise of likelihood and consequence of a hazard. For latent hostile hazards however the assessment becomes more complex and binary decision-making may be more appropriate. As such a categorical approach is more practical: either the risk to exposure exists at a location or it doesn't, based on some threshold probability.*

Any attempt to arrive at a suitable risk assessment for such a hazard therefore must be accompanied by sound measurement design and statistical analysis. This paper offers a method of developing risk assessments for hazards with measurable threshold values in hostile environments. The assessment uses risk discriminants for determining the risk of exposure to a hazard by calculating the product of the pervasiveness probability and prevalence probability of the hazard using logistic regression to determine the odds of the risk and cumulative probability charts of the hazard data collected to determine its prevalence, respectively.

INDEX TERMS: *Risk, health and safety risk assessment, risk discriminant, logistic regression, latent hazard, radiofrequency.*

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I. INTRODUCTION

When energy is confined and enclosed within boundariesit poses a potential health and safety threat. Such hazards include pressurized steam in pipes, water filled drains, gas tanks and to some extent, radio frequency (rf) waves inside a confined space.

For rf waves trapped inside an enclosed chamber the propagation is like air vibrating in a tube or plucking a string tied at both ends where single and multi-modes of vibration can occur. These are as a result of standing waves being set up from reflecting and incoming waves causing constructive and destructive interference known as hot and cold spots.

For the string tied at both ends and plucked at a point along its length,the wave speed depends on the tension and the mass per unit length of the string on which the wave must travel, $v = \sqrt{T/m/l}$. The vibrating string can then disturb the air around it, causing it to vibrate at various audible frequencies. For the bottle/ pipe closed at one end, blowing air faster across it increases the vibration of the air in the bottle thereby causing an increase in pitch and so different modes of standing waves are heard due to this increasing vibration.

Unfortunately electromagnetic waves in the 80 to1000MHz frequency range do not produce audible sound which is a disadvantage since these vibrations do not appeal to our sense of hearing and other suitable means of detection such as measurement will have to be done. This however makes us place our trust in the measuring device where sensitivity may be inconsistent. In addition, waves on a string and in a pipe can be treated as one dimensional, while the electric field vector, E field for electromagnetic waves can best be treated as two dimensional when propagating along a waveguide design enclosure. It is this complex arrangement of E field that is of safety interest for which a methodology for measurement, analysis and risk assessment has been proposed in this paper.

We are now faced with a concern of how best to measure and analyse this latent hazard. Surely there must be some model that can be relied upon to give the probability of occurrence of a hot spot (point of constructive interference) at a particular location within the waveguide or confined space based on the frequency of the rf, the angle of approach and the intensity of the waves. This probability model must take into account the predictors (independent variables) that will affect the outcome. The use of linear regression is one such way to deal with this analysis to see how the intensity, location of hot spots and frequency are all related and influence the probability of exposure to the hazard.

The simple linear regression however does not adequately address categorical values of ‘yes and no’, pass and fail’ such as in a binomial type distribution. Since the hazard whose risk is to be assessed here, i.e., rf waves hot and cold spots, is not concerned with an outcome that is continuous but rather specifies whether a physical entity such as intensity is above or below a threshold level, a two category case, i.e either there is a hot spot or there is not based on measured rf intensity, then the logistic regression is preferred for determining the odds and probability of risk of exposure to the hot spot.

This procedure examines the relationship between predictor and logistic transformations of proportions where the coefficients for each predictor can be adjusted to get a better linear fit, in other words it is used here to model the probability of fit of occurrence or not of rf intensity within an open empty rectangular confined space.

The method does not use least squares but rather maximum likelihood for estimation and error calculation.

II. LITERATURE REVIEW

A suitable risk assessment for safety and health takes into account the many contributors to the existence of the hazard. For organizations this may seem a hindrance to production and they must repeatedly decide whether risks are low enough on their premises. Occupational risk decisions must be taken based on pre-defined criteria that may not be suitable for all organizations but must be considered together with cultural diversity and responsibility in different workplace settings. According to [6] acceptance criteria in the workplace is important and usually overlooked. To improve risk assessments therefore the subjectivity in the decision process must be reduced and tailored to each occupation.

Reference [4]sees three types of risk analyses: qualitative, semi-quantitative and quantitative of which quantitative gives the most accurate analysis. There are situations in which the data are however difficult to obtain either due to measuring requirements or instrument and semi quantitative analysis has to be used [6].

The accuracy of risk assessments depends on the closeness to scientific procedures and true value, not withstanding the element of systematic errors which must be found and removed. Too many times however scientific criteria are absent making it difficult to construct the risk assessment model. The four key elements for a scientific risk assessment model are: knowledge or experience, broad risk evaluation, managerial analysis and decision evidence where the bounds of probability distribution constitute a limit to the determination of a risk. If not much is known about the hazard it is difficult to assign a specific probability. Probability is used to decide the belief of the operator which is subjective and not definite answers such as ‘yes’ or ‘no’[8].

Reference [1] lends some credence to both objective (probability distribution) and subjective judgment as a good combination. Expert input may be acceptable for certain hazards but for some latent onesthere is really no expert judgment given the complex nature of the hazard. Radiofrequency propagation is one such hazard that is complex with the ability to vary its configuration from three dimensional to two dimensional as in confined spaces such as waveguides. [7]

The development of a risk assessment can be challenging since there exists much uncertainty and focus on experience and prior knowledge instead of data measurement, design and analysis. Statistical and probabilistic models have been used to varying degrees to give an account on risks which have been seen to work well. [9]

Of keen interest to this paper is the development of a risk assessment for hazards that do not readily appeal to our five senses and as such requires a definite yes or no for violations to a specified threshold.

Electromagnetic waves have been known for over a century but have only been applied to technological use for the past three decades or so. With growing demand, the traffic density of data is increasing daily with varying configurations to match this demand. There is need to satisfy customers in wireless links for WiFi connections, telephone, internet, radio and television broadcasting, and as such propagation through buildings is increasing as service is required at offices, homes and often in confined spaces. As population density also increases throughout the world, we can expect that sources that generate RF waves will be in close proximity to most families and work stations. Our structures and buildings are designed to house humans and are of dimensions to suit entry and exit of people comfortably, it is however troubling to know that these entrance dimensions of buildings and shape may also allow RF waves to enter our space and intermingle with us. The problem is that domestic buildings act as waveguides for large waves where energy does not dissipate as rapidly as in free space; this can present a potential risk to our health [7]. In order to achieve the wide coverage, mobility, capacity and quality integrity that everyone so yearns for, more cells especially in the suburban and urban areas have to be placed within buildings, on top and just outside of buildings.

High frequencies are used in underground mines, manufacturing, communication, navigation, radio and television broadcasting and in the event of an emergency workers must be contacted prior to the event. The modelling of the rf propagation in mines uses a three dimensional approach with permittivity of air and a complex dielectric constant for determining receiver power, in the x (across walls), y (vertical) and z (down the tunnel) directions. Angles of incidence relative to the normal at the reflecting surfaces are used to calculate the parallel and perpendicular reflection coefficients for receiver power of vertically polarized waves.

Findings of this experiment revealed that complex permittivity is small in comparison with frequency and tunnel dimension and also that attenuation was found to be low if the waves are vertically polarized and the width of the tunnel is smaller than the height. If the waves are not vertically polarized then its component is less attenuated with movement down the tunnel leading a smaller attenuation rate than the vertical component and this was seen for 915 MHz [3].

The quality of a measurement is dependent on its uncertainty and gives the degree of confidence we can place in the quoted final value. To this end, there may be many contributors to the uncertainty in a measurement, one of which is sampling. The uncertainty due to sampling may therefore require considerable undertaking.

According to [2] 'The fitness for purpose of measurement results can only be judged by having reliable estimates of their uncertainty. For this reason it is essential that effective procedures are available for estimating uncertainties arising from all parts of the measurement process.'

Sampling quality therefore depends on the uncertainty accompanied by sampling. According to [2] there are two broad approaches to the estimate of uncertainty:

1) Empirical-which is the measurement method taking sampling and analytical considerations into account and
2) Modelling- (theoretical) which is the predictive approach where many assumptions are made

In validating results one may take routine samples on site which may in fact differ from those prevailing during validation, since you take a small part of a population which may be heterogeneous in nature. This heterogeneity may vary markedly from sample to sample. In its Addendum, IUPAC noted that 'the degree of heterogeneity is the determining factor of sampling error'. This shows the importance with which this topic is treated and that such factors of heterogeneity as random variability and selection bias remain target problems in properly managed sampling.

III. METHODOLOGY

Based on the discussions and findings in the literature review, no subjective risk assessment may be sufficient and adequate for complex hazards including rf waves. The literature reveals perceptions and facts on hazards and risks that can be either quantitative versus qualitative; statistical versus theoretical, threshold delimitations of yes or no; predefined criteria determinations; measurement methods; probability; uncertainty and contributors to hazards, all of which should be taken into account when considering an appropriate risk assessment.

In order to exude some understanding of rf behaviour in confined spaces for the development of a plausible probabilistic risk assessment for the prevalence and pervasiveness of its propagation, the following experiment was conducted at a local university in the Republic of Trinidad and Tobago.

A cuboid enclosure with smooth metallic inner wallsunbounded at the entrance and exit was constructed to act as a waveguide for wavelengths in the frequency range 60MHz to 800 MHz. Radio frequency waves were then transmitted down the guide and the maximum electric field intensities measured at 54 equally spaced locations for seven different frequencies representing the single TE 10 mode. The data collected for each frequency were then tabulated and intensities that fell above a certain threshold for a given frequency, were considered above normal and given a value of one,1, while those which fell below the threshold were a value of zero, 0. These categorical values were used in a logistic regression analysis with location (1 to 54) as the predictor variable, for determining the odds of threshold exposure and the probability of occurrence. The question of importance to the study is what arethe odds of exposure when the location is varied by one unit.In other words as location is changed inside an enclosed space that may be likened to a waveguide, what are the odds of being in a location that is above the E field thresholdand therefore the likelihood of exposure to hot spots as set by the exposure guidelines?

Such a concern may find importance in international safety standards forradio frequency propagation inside enclosed spaces. For such circumstances it does not matter how muchabove or below a person is exposed to the threshold but simply whether there was exposure or not.

The odds ratio, OR, in the logistic regression proposed here signifies the measure of importance between location and risk exposure to a hot spot in the confined space. If at location one, 1, and movement takes place to location two, 2, then the odds ratio as reported in Minitab Statistix gives the change in odds for that one unit movement increase of the location predictor, see Table II column 3. For this model the change in location from one to two, two to three, three to four, etc., the equation is given by: $[(P/1-P)_1/ (P/1-P)_2] = e^{ß0 + ß1x1}/e^{ß0 +}$

^{ß1x2}.P is the probability of occurrence of a hot spot and hence risk exposure while 1-P is the probability of no hot spot and hence no risk of exposure, while x1 and x2 are the two location changes. [P/1-P] are the odds for locations one and two.

The odds of occurrence is used to get the probability of a hot spot and hence the risk to exposure at a location. The probability of getting a one, 1, P(Y =1/X) is the probability of an outcome of 1 given a location X is used to get the pervasiveness probability¶1 of the hazard see Table IV, column 1.

While the pervasiveness probability tells through the odds, how likely a risk to exposure, of equal importance is how widespread or prevalent the threat and this is obtained through the prevalence probability, ¶2. This is read off the cdf charts in Figs I to IV, for the rf intensities at the 54 locations. For the cdf graphs the function F(X) describes the probability of an intensity or less found at a location. Of interest however is 1-F(X) which is the probability of getting intensities higher. This is the prevalence probability, see Table IV column 3.

IV. DATA COLLECTION

The intensity, frequency, P/F (hot spot/ no hot spot) and location values were tabulated as shown in Table 1. These were fed into the software for logistic regression output. The coefficients of importance were obtained along with best fit parameters between the model and collected data. The accuracy of the model is measured using deviance and goodness of fit tests.

TABLE I: RF DATA COLLECTED SHOWING INTENSITY, LOCATION, TE MODE, FREQUENCY AND THRESHOLD INTENSITY

Frequency = 112MHz; at threshold: -45db			Frequency =61.72MHZ; at threshold: -60db		
TE10 34DEG			TE10 40 DEG		
Intensity/ db	Location	P/F	Intensity/ db	Location	P/F
-44.5	1	1	-61	1	0
-80	2	0	-65	2	0
-62	3	0	-54	3	1
-47.5	4	0	-54	4	1
-47.5	5	0	-71.5	5	0
-46.5	6	0	-61.5	6	0
-54	7	0	-56.5	7	1
-55	8	0	-73	8	0
-49	9	0	-63	9	0
-41.5	10	1	-54	10	1
-44	11	1	-56	11	1
-42.5	12	1	-54	12	1
-46.5	13	0	-56.5	13	1
-48.5	14	0	-56	14	1
-41.5	15	1	-56	15	1
-45.5	16	0	-57	16	1
-49	17	0	-54.5	17	1
-41.5	18	1	-49	18	1
-42	19	1	-50.5	19	1
-41	20	1	-48	20	1
-43	21	1	-53	21	1
-44.5	22	1	-55	22	1
-44.5	23	1	-54.5	23	1
-40	24	1	-53	24	1
-38	25	1	-52.5	25	1
-43.5	26	1	-52	26	1
-40	27	1	-48	27	1
-42.5	28	1	-49.5	28	1
-45.5	29	0	-50	29	1
-46.5	30	0	-52	30	1

-44	31	1	-52.5	31	1
-43.5	32	1	-57	32	1
-49	33	0	-51	33	1
-38	34	1	-51	34	1
-43	35	1	-53	35	1
-39.5	36	1	-52	36	1
-42.5	37	1	-55.5	37	1
-52.5	38	0	-53.5	38	1
-46.5	39	0	-60	39	0
-45.5	40	0	-62.5	40	0
-45	41	0	-56	41	1
-48	42	0	-50.5	42	1
-46	43	0	-53.5	43	1
-47.5	44	0	-50.5	44	1
-48	45	0	-57	45	1
-42.5	46	1	-56.5	46	1
-51.5	47	0	-58.5	47	1
-51.5	48	0	-59	48	1
-44	49	1	-66.5	49	0
-43.5	50	1	-63	50	0
-53.5	51	0	-60	51	0
-52	52	0	-64.5	52	0
-70	53	0	-56	53	1
-48.5	54	0	-51.5	54	1

TABLE II: COEFFICIENTS AND ODDS RATIO DATA

<table>
<tr><td colspan="6">Odds Ratio equation: $[(P/1-P)_1/ (P/1-P)_2] = e^{ß0 + ß1x1}/ e^{ß0 + ß1x2}$
Logistic Equation: $Y' = Ln (P/1-P) = ß_0 + ß_1 x_1$</td></tr>
<tr><td>Freq/ MHz</td><td>Equation $Y' = Ln (P/1-P)$</td><td>Odds ratio</td><td>Confidence interval 95%</td><td>VIF</td><td>SE Coeff for i) and ii)</td></tr>
<tr><td>112</td><td>$Y' =0.151 - 0.0109x$</td><td>0.98</td><td>(0.9555; 1.0239)</td><td>1</td><td>i) 0.554
ii) 0.018</td></tr>
<tr><td>61.72</td><td>$Y'=1.038 + 0.0080x$</td><td>1.01</td><td>(0.9672; 1.0505)</td><td>1</td><td>i) 0.646
ii) 0.021</td></tr>
<tr><td>71.2</td><td>$Y'=1.617 - 0.0003x$</td><td>0.99</td><td>(0.9549; 1.0467)</td><td>1</td><td>i) 0.741
ii) 0.023</td></tr>
<tr><td>62.7</td><td>$Y'=0.518 - 0.0024x$</td><td>0.9976</td><td>(0.9632; 1.0332)</td><td>1</td><td>i) 0.568
ii) 0.018</td></tr>
<tr><td>180</td><td>$Y'=-0.552 - 0.0083x$</td><td>0.99</td><td>(0.9557; 1.0291)</td><td>1</td><td>i) 0.584
ii) 0.019</td></tr>
<tr><td>354</td><td>$Y'=1.415 - 0.0368x$</td><td>0.96</td><td>(0.9285; 1.0007)</td><td>1</td><td>i) 0.625
ii) 0.019</td></tr>
<tr><td>711</td><td>$Y'=0.063 - 0.0495x$</td><td>0.96</td><td>(0.9091; 0.9963)</td><td>1</td><td>i) 0.607
ii) 0.023</td></tr>
</table>

TABLE III: GOODNESS OF FIT

Frequency / MHz	Goodness of fit test for: Deviance.		Analysis of variance: Wald test for Regression and Location resp.	
	Chi square	P value	Chi square	P value
112	74.18	.023	0.38 0.38	0.535 0.535
61.72	57.07	0.292	0.14 0.14	0.706 0.706
71.2	48.66	0.606	0.00 0.00	0.991 0.991
62.7	72.15	0.034	0.02 0.02	0.893 0.893
180	67.08	0.078	0.19 0.19	0.659 0.659
354	69.01	0.057	3.71 3.71	0.054 0.054
711	54.48	0.380	4.49 4.49	0.034 0.034

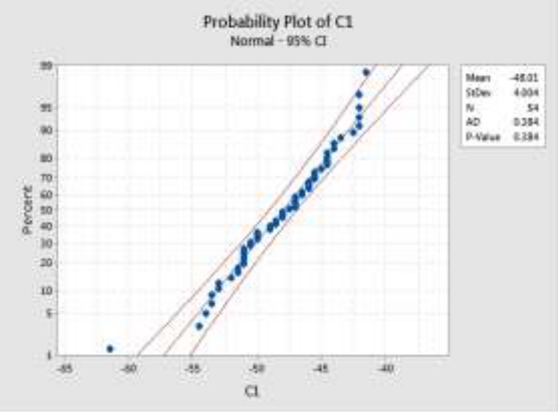


Figure I: Probability plot for E field intensities TE10/ 711MHz

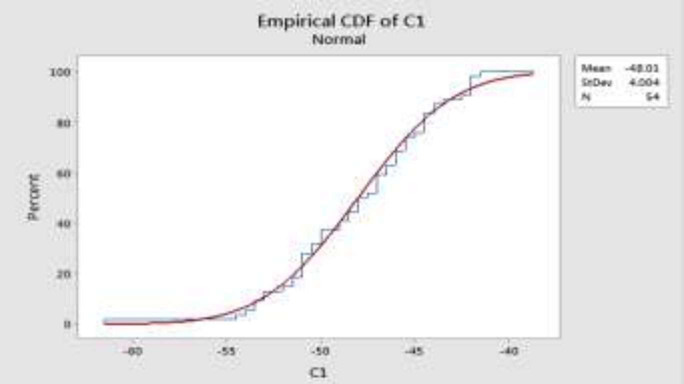


Figure II: CDF plot for E field intensities TE10/ 711MHz

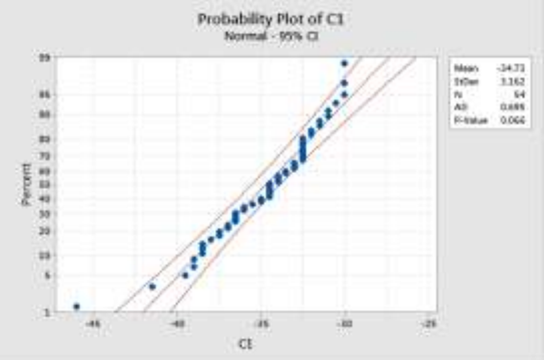


Figure III: Probability plot for E field intensities TE10/ 354MHz

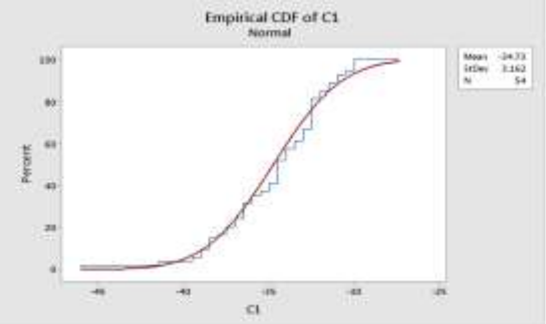


Figure IV: CDF plot for E field intensities TE10/ 354MHz

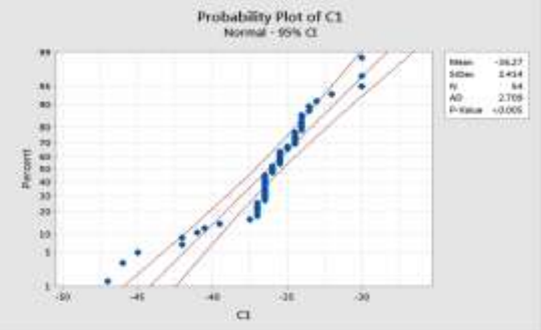


Figure V: Probability plot for E field intensities TE10/ 180MHz

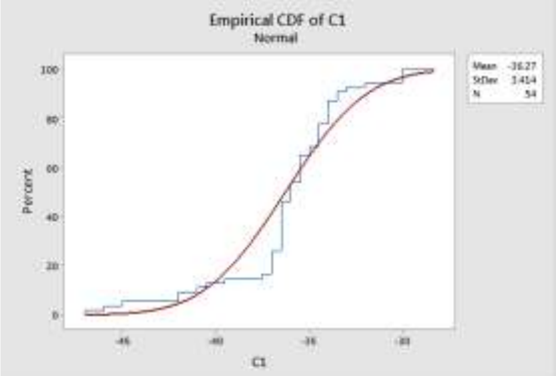


Figure VI: CDF plot for E field intensities TE10/ 180MHz

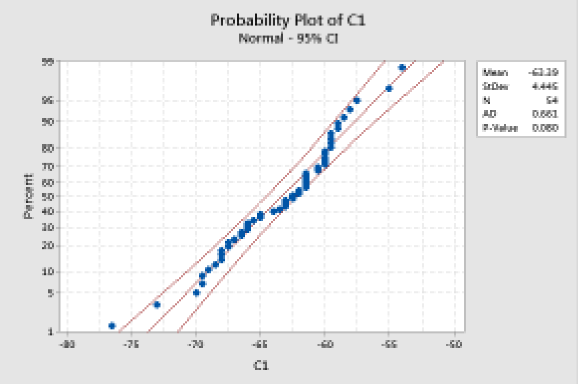


Figure VII: Probability plot for E field intensities TE10/ 62.7MHz

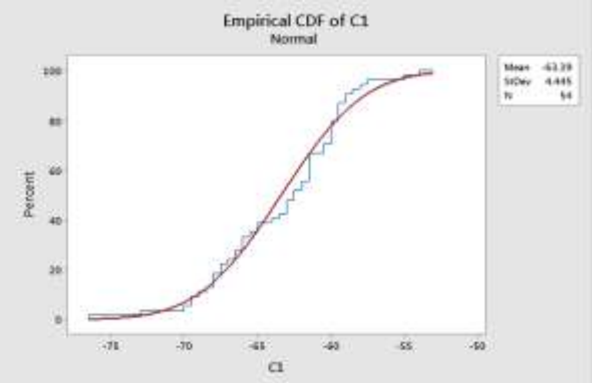


Figure VIII: CDF plot for E field intensities TE10/ 62.7MHz

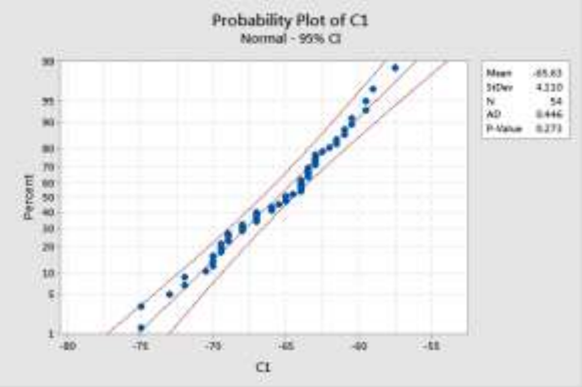


Figure IX: Probability plot for E field intensities TE10/ 71.2MHz

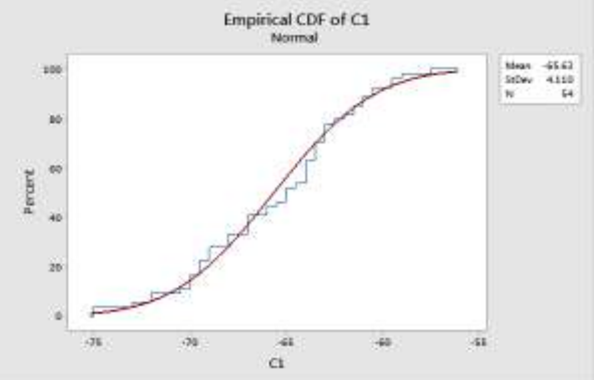


Figure X: CDF plot for E field intensities TE10/ 71.2MHz

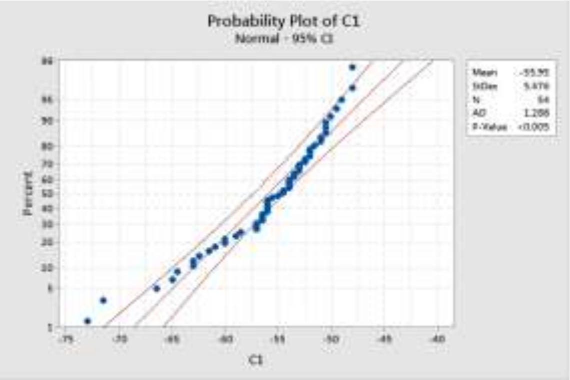


Figure XI: Probability plot for E field intensities TE10/ 61.72MHz

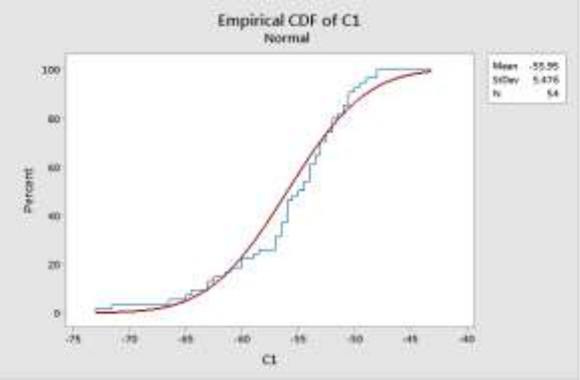


Figure XII: CDF plot for E field intensities TE10/ 61.72MHz

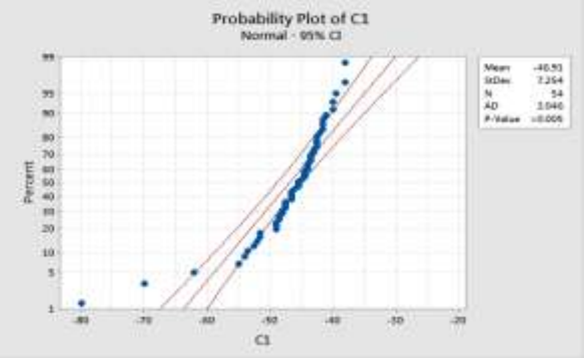


Figure XIII: Probability plot for E field intensities TE10/ 112MHz

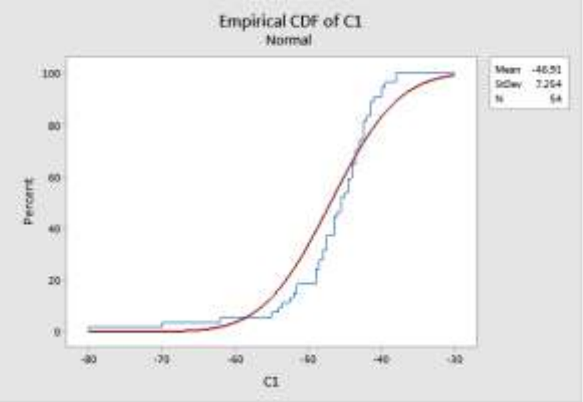


Figure XIV: CDF plot for E field intensities TE10/ 112MHz

V. PROCEDURE

The data (only two shown of the seven sets collected) in Table I shows measured maximum intensities for the TE10 mode at 112MHz and 61.72MHz with threshold intensity values of -45db and -60db respectively. The threshold values are based on the frequency of propagation and the danger posed since not all frequencies will have the same threat as usually is the case in the standards on rf exposure limits. The threshold however has been arbitrarily chosen only to highlight the method of developing the risk assessment and can of course be modified given the situation. Our threshold gives a value of ‘1’ for any intensity at -45db and above which implies that there is the potential for exposure to a hot spot at the location for the 112MHz and ‘0’, for any intensity below -45db which implies that you are not at a hot spot and do not run the risk of exposure. The 54 locations are equal squares mapped out inside the confined space. The maximum intensities were measured at fixed heights from the floor for all frequencies.

VI. ANALYSIS

An analysis of the collected data is necessary for goodness of fit details and errors in the data spread and consistency with the distribution model of choice. Table II gives theVIF which is the collinearity of the data collected and is shown to have a value of 1.00 which is good since the cut-off is usually taken as between 7 and 10. Column 3 shows the standard error, S.E. values for i) the constant, ß$_0$and ii) the locationß$_1$. The constant and location coefficient as well as the odds ratio can also be found in this table and used to get the probability of a hot spot.

Table III shows that the Pvalue for deviance supports that the model fits the data for the various frequencies. This suggests therefore that using the odds ratio to obtain odds or probability of hot spots is acceptable.

Figs I to XII show the cumulative probability and the cumulative distribution plots for all seven frequencies. The probability plot reveals that there are outliers or maximum intensity values for the maxima intensities measured. The probability of obtaining an intensity value at a particular location for a known frequency can be chosen off the cumulative distribution chart. So for example, intensity -62db and below at location 2 (see Table IV) will have a probability of occurrence of 0.02 i.e. F (x) = 0.02. Theprobability of occurrence for intensity above -62db at this location, 2, is therefore 1-F(x) = 0.98, column 3 the prevalence probability, Table IV.

The pervasiveness probability, ¶2 is the probability of getting a one, or hot spotand hence risk of exposure for the same location value, x = 2. The pervasiveness probability of 0.532255 for this location is seen in column 1 of Table IV.

TABLE IV: Risk Discriminant Calculation

Frequency: 112MHz			
Threshold -45db			
Threshold probability for -45db = 0.80			
Pervasive probability ¶1	Odds	Prevalence probability¶2	Risk Discriminant ∏
0.534968	1.15038	0.4	0.21398712
0.532255	1.13791	0.98	0.52161004
0.529541	1.12558	0.94	0.49776812
0.526824	1.11338	0.45	0.23707089
0.524106	1.10131	0.45	0.23584783
0.521387	1.08937	0.43	0.22419638
0.518666	1.07756	0.8	0.41493305
0.515945	1.06587	0.79	0.40759622
0.513222	1.05432	0.62	0.31819758
0.510498	1.04289	0.21	0.10720467
0.507774	1.03158	0.34	0.17264328
0.50505	1.02040	0.22	0.11111096
0.502325	1.00934	0.43	0.21599974

0.4996	0.99840	0.6	0.29976
0.496875	0.98757	0.21	0.10434375
0.49415	0.97687	0.36	0.17789409
0.491426	0.96628	0.62	0.30468402
0.488702	0.95580	0.21	0.10262740
0.485979	0.94544	0.18	0.08747616
0.483256	0.93519	0.14	0.06765587
0.480535	0.92505	0.28	0.13454975
0.477815	0.91502	0.4	0.19112583
0.475096	0.90510	0.4	0.19003825
0.472378	0.89529	0.14	0.06613294
0.469662	0.88559	0.1	0.04696623
0.466948	0.87599	0.25	0.11673706
0.464236	0.86649	0.14	0.06499306
0.461526	0.85710	0.22	0.10153576
0.458819	0.84780	0.36	0.16517466
0.456113	0.83861	0.43	0.19612868
0.453411	0.82952	0.34	0.15415958
0.450711	0.82053	0.25	0.11267765
0.448014	0.81163	0.6	0.26880813
0.44532	0.80284	0.1	0.04453195
0.442629	0.79413	0.28	0.12393606
0.439941	0.78552	0.11	0.04839355
0.437257	0.77701	0.22	0.09619664
0.434577	0.76858	0.75	0.32593293
0.431901	0.76025	0.43	0.18571735
0.429228	0.75201	0.36	0.15452222
0.42656	0.74386	0.38	0.16209282
0.423896	0.73579	0.58	0.24585968
0.421236	0.72782	0.36	0.15164509
0.418581	0.71993	0.59	0.24696296
0.415931	0.71212	0.58	0.24123994
0.413285	0.70440	0.22	0.09092279
0.410645	0.69677	0.69	0.28334498
0.40801	0.68921	0.69	0.28152657
0.405379	0.6817	0.34	0.13782900
0.402755	0.67435	0.25	0.10068868
0.400136	0.66704	0.82	0.32811122
0.397522	0.65981	0.71	0.28224076
0.394915	0.65265	0.97	0.38306717
0.392313	0.64558	0.6	0.2353877

VII. THE RISK ASSESSMENT MODEL

Intensity measurements of rf waves for all 54 locations are taken and tabulated as shown in Table I. These values are then placed in Minitab and the software used to generate the results seen in Tables II and III from the logistic regression function. Unlike Table I which shows values for only two frequencies, Tables II and IIIgive values for all seven frequencies used in the study.

Table II shows the odds ratio for 112MHz of 0.9891 which implies a reduction to exposure by 0.0109 or 1.09% for each one unit moved across the confined space from location to location. The odds ratio for a two unit move is 0.978, three unit move is 0.968 and four unit move is 0.957 or reduction in odds of exposure by 2.2%, 3.2% and 4.3% respectively. This does not necessarily mean that there is a reduction in the probability of exposure. The odds ratio for each location is obtained by substituting for the location x and placing in Y' in Table I.

Example; the odds for one location movement or increasing the location by one unit is$e^{0.151-[0.109 x 1]}$ / $e^{0.151-[0.109 x 2]}$ = 0.9891 as shown in Table I for moving from location one to two. For a two unit change say from location 1 to location 3 we have $e^{0.151-[0.109 x 1]}$ / $e^{0.151-[0.109 x 3]}$ = 0.0.978, for the three unit move say from location 1 to 4:$e^{0.151-[0.109 x 1]}$ / $e^{0.151-[0.109 x 4]}$ = 0.968.

The discriminant ∏ is the product of the pervasiveness probability ¶1 and the prevalence probability for each location ¶2 and is ∏ = ¶1 x ¶2.

The information in Table IV shows the highest risk discriminant of 0.52 for location 2 and lowest of 0.0445 for location 34. This implies that location 2 has the highest risk of exposure to hot spots while location 34 has the lowest risk. Points with high risk discriminants have greater potential for hazard exposure.

VIII. DISCUSSION AND CONCLUSION

The risk discriminants determined in this paper give the potential for risk exposure to a hazard based on its pervasiveness or severity, and, pervasiveness based on how widespread it is across all locations of interest for which the logistic regression was found to be suitable. The logistic regression is ideal for latent hostile hazards where critical information really only requires to know whether the hazard (hot spot) exists or not and place into a category of above threshold or below (pass/ fail).

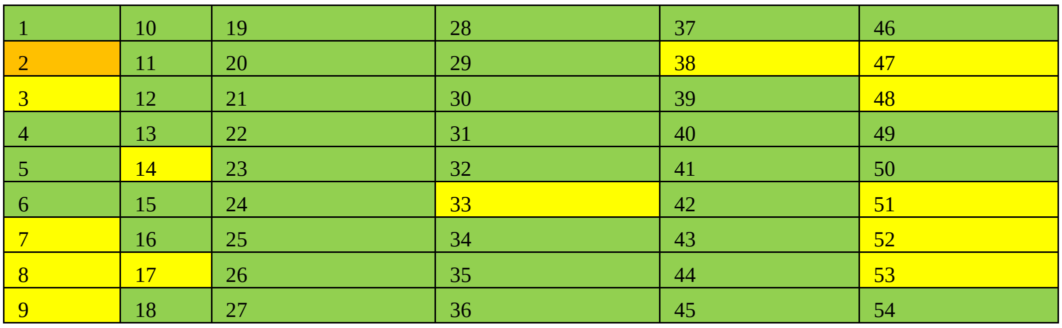
As shown, only one predictor variable, location was used in the model although many more can be included based on the influence they have on the dependable variable. The model developed was for an empty enclosure but could have been extended to an occupied space with people and artefacts inside where attenuation, size and movement considerations would be included together with location as predictors.

The goodness of fit of the data to the distribution model of choice is important for accuracy of the prevalence probability.

For this model based on rf propagation for the 112MHz rf propagation, the odds of exposure are in fact decreasing as we move from one location to the other in one unit increased steps. It could have also been easily shown for two step and three step movements as shown in the text earlier.

Determining a risk of exposure to highly dangerous, contagious latent hazards requires empirical verification and not just subjective, uninformed unsubstantiated claims. In this regard, the use of statistics for pervasiveness and prevalence are more desirable for a risk assessment than the widely used and accepted approach of consequence and likelihood.

Fig XV patterns the risk discriminants found in Table IV and gives a quick overview of trouble areas.



1	10	19	28	37	46
2	11	20	29	38	47
3	12	21	30	39	48
4	13	22	31	40	49
5	14	23	32	41	50
6	15	24	33	42	51
7	16	25	34	43	52
8	17	26	35	44	53
9	18	27	36	45	54

Figure XV:Risk Discriminant Map for 112 MHz

The risk discriminant map is scaled as follows:

$1 < \prod < 25$ = green and implies low risk, $26 < \prod < 50$ = yellow and implies a risk to exposure, $51 < \prod < 75$ = orange and implies unsafe conditions, $76 < \prod < 100$ = red and implies safety and warning alert. As seen in this study the 112MHz rf reaches highest at orange in location 2 (no red) giving unsafe limits at this location. So for this study the confined space is relatively safe for this threshold and this frequency of rf radiation.

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