Statistical Prediction Model of Rain and Dust Storm Worst Month in Microwave - Millimeter Wave Band

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Abstract: - Recent development in the field of advanced communication services and applications has triggered interest in super high frequencies and significantly increased research activity in millimeter wave. In this paper, a new method of calculation of worst month and statistical model has been developed for use in the rain and dust storm to statistically predict the probability of exceedance are presented. A thorough review of various prediction models previously developed for rain or sand and dust storm are comprehensively carried out. Traditionally, the meteorological conditions are difficult to predict due to uncontrolled variations. Statistical distributions have been fit-to-data type with little or no physical insight. However, studies in the statistical modelling of climate data rain and sand and dust storm for attenuation signal in literature are limited. The new model was fed with data collected from Sudan in five main climatic zones at specific areas between 23°.10°.0'-37°.15°.0' E and 21°.02°.0' - 09°.05°.0' N. Moreover, formula for prediction of the worst-month long-term statistics for different weather induced propagation impairments was developed. The knowledge of weather phenomenon is usually available several periods in advance, which has the potential to improve or eliminate losses due to optimized convergence in tropical, arid, and desert. The main contribution of this study is to assist in the design of both terrestrial and space radio links using frequencies above 10 GHz in range of microwave and millimeter wave bands.

Keywords: Worst-Month Propagation, Probability, Attenuation, Sand and Dust storm; Microwave & Millimeter-wave.

I. INTRODUCTION (HEADING 1)

Radio links operating at frequencies above 10 GHz are subject to severe propagation impairment. Over the few earlier decades, radio communication services and applications underwent broad development. The demands that a radio spectrum has to satisfy are larger through the day. Having in intellect just right quality and fee powerful solutions, a brand new radio sys-tem has to be designed cautiously from the very commencing [1-4]. One of the most important characteristics of the propagation of signal are environment of the path (attenuation) loss and an accurate prediction of the attenuation caused by rain or dust storm are essential for the design of communication systems. Moreover, an accurate estimation of the propagation losses provides a good basis for a proper selection of base station locations and a proper determination of the frequency plan. In recent years have become parts and different regions of the world are suffering from climate change, which in turn became the affect of service operations, which must be studied and know the deal, including phenomena such as ice in places were not out, as well as dust storms[5-6].

Rainfall and dust storm prediction is one of the most imperatives, important and demanding operational tasks and challenge made by meteorological services around the world. It is important to consider many technical issues before going to design and establish an expensive Wireless system. It is necessary to see the mathematical predictions or calculations of different parameters before going to design such type of systems. The quick growth in Links in wireless communications made it possible for the different area around the world as well as rural people to access the internet and cellular phones as well other applications. How-ever, this growth came with many inherent problems. Some of which include poor signal transmission or reception in various climatic conditions.

Figure 1 world’s different climates zones tropical and arid.
Microwave and Millimeter wave bands links in space and terrestrial are prone to variations in attenuation over a large range due to rain and dust storm in links located in a raid and a tropical region, in some bad cases become more than 3 dB/km. traditionally, it has been considered to be part of meteorological conditions, unavoidable variations. Propagation conditions vary from month to month and from year to year, and the probability of occurrence of these conditions may vary by as much as several orders of magnitude. Some phenomena occur only rarely, requiring many years of observation to make any conclusions. For instance, elevated ducting may occur only several times per year in some locations, and in many areas, rain intense enough to affect propagation paths occurs for less than 1 percent of a year.

The outstanding sections of this paper are as follows: Effect of SDS to the higher frequency band and Microwave links is described in Section II. In Section III, we present the attenuation and development of prediction models and discussions. Finally, we end this study in Section IV with conclusion and recommendation and future work.

II. RELEVANT STUDIES

Relevant Studies: Rain attenuation is the dominant propagation impairment at frequencies above about 10 GHz. In addition, other impairments such as gaseous absorption, cloud attenuation, melting layer attenuation, and a tropospheric refractive effect becomes increasingly important with increasing operating frequency. A number of prediction models are available for the estimation of individual components [1]-[4]. However, methodologies that attempt to combine them in a cohesive manner are not widely available. This is partly due to the paucity of reliably measured data required to compare and verify such approaches.

Estimates statistics of various propagation effects that should be considered in the design of earth-space links. Propagation effects such as absorption, scattering and depolarization by hydrometeors, absorption due to atmospheric gases, multipath effects and ionosphere effects (typically only notable below 1GHz) can cause signal fade and need to be considered when implementing a satellite system to maintain a quality of service. Statistics for propagation effects provide an attenuation cumulative distribution function (CDF), which can be combined with further ITU-R recommendations to create an overall average annual attenuation CDF. Other ITU-R recommendations include rainfall rate, P.837-5, rain attenuation, P.838-3, cloud attenuation, P.840, and gas attenuation, P.676. Significant of study it is presence of the various forms of precipitation such as rain, snow, cloud and fog in a radio wave or microwave path are always capable of producing major impairments to terrestrial communications. It is, therefore, necessary to identify and predict the overall impact of every significant attenuation effect along any given path. A procedure for predicting the combined effect of meteorological factors attenuation and several other propagation impairments along earth or space links is presented.

There are several types of weather forecasts made in relation to time:
- A short-range forecast is a weather forecast made for a time period up to 48 hours.
- Medium range forecasts are for a period extending from about three days to seven days in advance.
- Long-range forecasts are for a period greater than seven days in advance but there are no absolute limits to the period.

Table: Summary of state

<table>
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<tr>
<th>Years</th>
<th>References</th>
<th>Locations</th>
<th>Highlights</th>
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<td>2000-2010</td>
<td>Bashir[1]</td>
<td>Malaysia(1) Colombia(1) South</td>
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<td>Yagassen[1]</td>
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<td>Emiliani[2]</td>
<td>Taiwan (1) Sudan(1)</td>
<td>statistics of rain, and dust storm for the site</td>
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<td>Villiers[4]</td>
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<td>• worst month distribution estimation problem</td>
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<td>because distributions may be predicted for each</td>
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<td>Crane[8]</td>
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<td>Musa [5]</td>
<td>Norway(1) Malaysia(1)</td>
<td>then readily apparent</td>
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<td>after</td>
<td>Ting[9]</td>
<td>Nigeria(1) Iran(1)  Iraq(1) Syria(1)</td>
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<td>Thorvaldsen[6]</td>
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Meteorological data are used to give an indication of the statistical rate of dust storm occurrence of a given of cross talk. As we mention in literature dusty seriously influences the performance of a communications satellite and ground link. The concept of worst-month plays an important role in space and earth links design where there is a need to know the design margin that must be met in any particular month of the year. Worst-month statistics can be applied to quantities such as dust storm attenuation, visibility and polarization planes. The worst-month statistics for a given link are obtained by compiling a composite curve using the highest exceedance
probability obtained in any calendar month at each threshold level.
The worst-month and annual statistics is related by the following ratio:
\[ Q = \frac{X}{Y} \] (1)
Where \( X \) is the average worst-month probability and \( Y \) is the average annual probability for the same threshold. \( Q \) is a function of the occurrence month level and the climatic region. Similar climatic regions will have similar values of \( Q \) in percentage. From a long term (1990-2014) dust storm data more than twenty-five years data, we could find the average of the highest frequency of occurrence of dust storm events happens in the June in Capital Khartoum. Hence, June is the worst–time statistics. Optical visibility is directly related to the severity of dust-storm. Low visibility implies high number concentration of particles while low number concentration of particles represents high visibility the following model [1]-[8-9] gives the monthly probability of visibility to be less than a distance (li):
\[ P(V < li) = \left[ \frac{(ST 	imes t 	imes li)}{(30 	imes 24 	imes L)} \right] \times 100\% \] (2)
Where, \( P \) is the probability of exceedance in %, \( t \) is a average dust-storm duration in hours, \( V \) is optical visibility in meters, \( T \) is an average number of storms per worst-month, and \( L \) is the maximum length of visibility considered in meters. We have been able to trace from data obtained from the Sudan Meteorological Authority (SMA -2014) that the visibility ranges from 0.1 km to 5 km and more in very few cases. The maximum length of visibility \( L \) considered in this case 1000 m. The table below depicts the visibility and its corresponding probability statistic results of the worst-month.

### Worst-Month Visibility Statistics

For a preselected threshold level, the worst-month is defined as the month with the highest probability of exceeding the threshold level. Optical visibility is directly related to the severity of dust-storm. Low visibility implies high number concentration of particles while low number concentration of particles represents high visibility.

#### III. METHODS

The methodology of your paper should be described in this section. The fading and enhancement distributions for the average worst month obtained from the methods can be converted to distributions for the average year by employing the following procedure: Step 1: Calculate the percentage of time PW fade depth \( A \) is exceeded in the large tail of the distribution for the average worst month obtained from the methods can be calculated is the required annual value \( p \). Following, step 2: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 3: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 4: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 5: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 6: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 7: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 8: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 9: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 10: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \).

\[ p = 10^{-\frac{AG}{10}} p_w \] % \hspace{1cm} (4)

If the shallow fading range of the distribution is required, follow the method of Step with the following changes: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 1: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \). Following, step 2: Convert the value of \( p \) obtained to an annual value by using, and use this annual value instead of \( p \). The value of \( p \) calculated is the required annual value \( p \).

The meteorological data that used in this study has been brought from SMA, Sudan for 10 years from 2004 to 2014 for 5 meteorological stations over the country with 1756 total number of examples. Figure 2 shown general method the used in the study. In addition to, figure 3 shown.

![Figure 2: Flow chart of Methodology](image)

Millimeter wave frequencies for ground or satellite links are prone to variations in attenuation over a large range due to rain and dust storm, more than 30 dB some time. Traditionally, it has been considered to be part of meteorological conditions, unavoidable variations. A mathematical model is often an approximate representation of a more complex system. It is important to consider many technical issues before going to design and establish an expensive Wireless system. It is necessary to see the mathematical predictions or calculations of
different parameters before going to design such type of systems.

A mathematical model is often an approximate representation of a more complex system. In modeling complex systems, model parameters often abound in number. The value of these parameters may be approximately determined through the fitting of model predictions with calibration data obtained from laboratory experiments, first principle arguments, ab initio calculations, more refined models, etc. Unfortunately, repeating a given experiment multiple times may yield different results that are suitably described by a statistical distribution.

Consequently, model parameters obtained from calibration data sources are themselves often described statistically. This statistical model parameter uncertainty then potentially affects all future predictions that make use of this model. Major task at hand is to propagate this model parameter uncertainty throughout subsequent calculations, thus quantifying the statistical behavior of derived outputs. We refer to this task as uncertainty quantification from statistical model parameter uncertainty.

![Figure 3: Five meteorological stations of study in Sudan](image)

**IV. RESULTS AND DISCUSSION**

Prediction models for the purpose of calculating signal propagation and performing fading predictions are empirical. Empirical models are the result of the application of mathematical regression techniques on measurement data and therefore result in a relationship that describes a variable’s dependency under certain given conditions. Empirical prediction models often provide a fair description of the fading process for distances and frequencies that lie within the data range for which measurements have actually been collected. The whole process is iterative and may go through many redesign phases before the required quality and availability are achieved shown in Figure 2. The quality of satellite communication systems can be seriously affected by variable climatic phenomena such as rain and turbulence. For the design of communication system a required availability, statistical knowledge of climatic propagation effects is essential. Predicting attenuation due to dust storm is an important but complex problem, and a variety of models have been developed [2]. Different approaches have been adopted by researchers [13] to evaluate microwave and millimeter wave signal attenuation due to sand and dust storm in terms predicting modelling. In addition, the restrained use of MW and MMW bands for commercial operations is due to severe sand and dust storm attenuation. Attenuation experienced in arid and semi-arid region is caused by considerably wind-blown and sand and dust turbulent atmosphere as compared to other parts of the world. Propagation conditions vary from month to month and from year to year, and the probability of occurrence of these conditions may vary by as much as several orders of magnitude. Some phenomena occur only rarely, requiring many years of observation to make any conclusions. For instance, elevated ducting may occur only several times per year in some locations, and in many locations, rain intense enough to affect propagation paths occurs for less than 1 percent of a year. In parts of India at locations where the monsoon occurs some years but not others, several significant rain events may occur one year but not the following year.
Worst-month statistics is of interest to those faced with designing a system to meet performance criteria expressed in terms of a percentage of any calendar month, or of any contiguous 30-day period. The system designer, in this case, needs to find the percentage of time that some threshold value of attenuation or rain rate and dust storm will be exceeded within a given month. For every threshold value, there corresponds a month of the year having the highest percentage of time exceeding the threshold (i.e., the percentage exceedance). This is designated the "worst-month" for that threshold. The percentage exceedance in this month, to be expected once every year or every given number of years, is of most interest. For high rain rates or high visibility in dust storm, the worst-month would probably correspond to the period of highest thunderstorm intensity or frequency whereas the worst-month for lower rain rates might be when most rainfall is of the steady, strati form variety.

V. CONCLUSION
Implications of the results and future research directions are also presented. The main findings from this work can be summarized as follows: various prediction models developed for rain or sand and dust storm are comprehensively described. Secondly, determination of the attenuation statistics is indispensable in planning and designing of wireless communications systems and links. Worst-month statistics of total attenuation were studied by using data collected with 5 radiometers in the Graz area at 3 different frequencies. Reasonable agreement with the Bashir model (6) was found. The results obtained agree quite well with the last year-to-worst-month relation for annual outage probabilities lower than around 0.1% and with for probabilities higher than 1%. However, the data would seem to indicate that a constant Q would be more appropriate in the range1 to around 30%. Some further study of this behavior would be necessary.

ACKNOWLEDGMENT (Heading 5)
We wish to thank Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia (UTM), Malaysia for providing the facilities, tools, and equipment for the radio signal propagation research.

REFERENCES

[9] Per Thorvaldsen and Ingvar Henne “Long-term propagation measurements on a line-of-sight over-water radio link in Norway”