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PERFORMANCE IMPROVEMENT OF INTELLIGENT WEATHER SYSTEM

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ABSTRACT

Prediction of channel characteristics can be of immense value in improving the quality of signals in high frequency satellite systems. Atmospheric properties like rain, snow, gaseous, cloud, fog, scintillation can have a distorting effect on signal fidelity of Ku and Ka bands, thus resulting in excessive digital transmission error. This loss of signal is commonly referred to as signal attenuation. Signal attenuation impacts the QoS in wireless and satellite networks. Accurately predicting channel attenuation due to atmospheric conditions can enable mitigation planning by adaptively selecting appropriate modulation, coding, transmitted power level, transmission rate and configured frame size. The aim of this paper is to estimate different attenuations using predicted signal-weather correlated database in collaboration with ITU-R propagation models combined with interpolation methods, gateway, and ground terminal characteristics. An intelligent decision support system is used for accurately calculating the attenuations. In this project we are calculating rain attenuation. The fuzzy logic is added into the system. The fuzzy system will determine the ambiguous signal during the attenuation performed.

KEYWORDS: Intelligent system, Fuzzy Logic, International Telecommunications Union Radiocommunications (ITU-R), Rain attenuation.

INTRODUCTION

Rain attenuation (RA) is major source of impairment to signal propagation at microwave and millimeter wavebands. These impairments become particularly severe at high frequencies, especially above Ku band. As such, it is extremely hard to optimally manage satellite dependent network resources that are impacted by weather attenuations. Thus, the need arises to properly predict significant attenuation factors that affect quality of service (QoS) [1].

To improve receive signal over satellite communications in DVB-S, We propose the fuzzy logic to deploy over the system. Rain attenuation is a dominant source of attenuation over Ku-band satellite communication. Because of the frequency of Ku-band was affected in rhythm of rain attenuation. In case of both of them are synchronized, the signal will loss or attenuated. This is vital problem to occur in Ku-band where high frequency is deployed [3]. In this paper, we use ITU-R models to accurately compute rain, gaseous absorption, cloud, fog and tropospheric scintillation attenuations as a function of both propagation angle and rainfall rate. This data will supply the intelligent system (IS) with a mechanism to better estimate satellite networking parameters such as link and queuing characteristics. The derived parameters would enable the IS to maintain quality of service and service level agreements.

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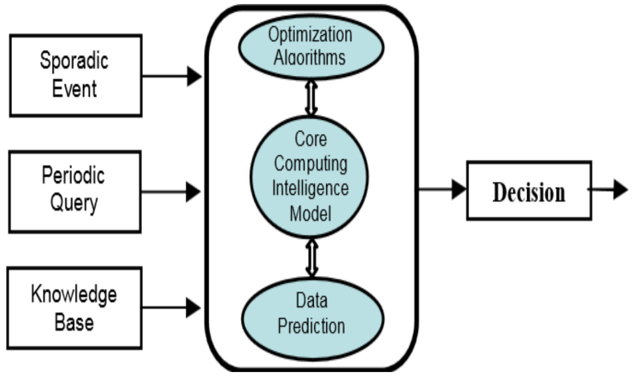

Fig.1 Network Optimization Decision Support System

Fig.1 shows the high level architecture of the network optimization decision support system. Weather attenuation, power, modulation, and coding information are used to obtain optimal decision. The work presented in this paper fits in the data prediction module and the interface to the core computing intelligence model of the decision support system. We use ITU-R models to accurately compute rain, gaseous, cloud, fog and scintillation attenuations as a function of both propagation angle and rainfall rate [1].This data controlled by the intelligent system via a Fuzzy Logic decision mechanism, provide a better estimate satellite networking parameters such as link and queuing characteristics. The derived parameters would enable the IS to maintain QoS.

Problem Defination

Rain is a dominant source of attenuation for Satellite networks over higher frequency bands. The signals should be properly received and transmitted with attenuation or not. If SNR is better , we will assume the quality of signal as better. In term of QoS, end user must get quality signal from transmission link weather rain attenuation or clear sky. Service must be strength and quality of signal must be maintained. In order to achieve this, we proposed a good process which can resolve the problem of rain attenuation by applying fuzzy logic inside the exiting Intelligent system.

RAIN ATTENUATION

Long-term statistics of slant-path RA for any given location at frequencies up to 55GHz is provided using ITU-R estimates. With respect to altitude RA's behaviour can be computed for any location and any frequency, based on frequency sample, as follows:

1) Mean rain height above mean sea level hR, can be obtained from 0 ° C isotherm h0 as:

hR = h0 + 0.36 km (1)

2) To compute slant-path length Ls below rain height, the following formulas are used,
where Re: radius of Earth (km)

$$a)\ \theta < 5°:\ Ls = \frac{2(hR - hS)}{(sin^2\theta + \frac{2(hR-hS)}{Re})^{\frac{1}{2}} + \sin\theta}\ km$$

$$b)\ \theta \leq 5°: Ls = \frac{(hR - hS)}{sin\theta}\ km$$

if (hR – hS) ≤ 0 ⇒ predicted RA for any time percentage is equal to zero and the following steps are not required.

3) Calculate horizontal projection Lg of slant-path length

$$Lg = Ls\, cos\theta\ \ km$$

4) Find rainfall rate, Rp, for exceeded p = 0.01% of an average year

$R_{0.01}$ = 0 ⇒ RA = 0 for any time percentage and the following steps are not required. Compute specific attenuation, γR, using frequency dependent coefficients for k, α and Rp for p = 0.01% by using: $\gamma_{0.01} = K(R_{0.01})^{\alpha}\ dB/km$ (2)

5)For linear and circular polarization and for all path geometries, coefficients in (2) can be computed.

$$K = [K_H + K_V + (K_H - K_V)cos^2\theta\ \cos 2\tau]/2$$
$$\alpha = [K_H\alpha_H + K_V\alpha_V + (K_H\alpha_H - K_V\alpha_V)cos^2\theta\ \cos 2\tau]/2k$$

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where, K_V, α_V and K_H,α_H are constant coefficients of vertical and horizontal polarizations respectively. θ is the path propagation angle and τ is the polarization tilt angle relative to the horizontal, equal to 45 degree for circular polarization.

Calculate horizontal reduction factor, rp for p = 0.01% :

$$r_{0.01} = \frac{1}{1 + 0.78\left(\sqrt{\frac{L_G \gamma_{0.01}}{f}}\right) - 0.38(1 - e^{-2L_G})}$$

Calculate vertical adjustment factor, Vp, for p = 0.01% :

$$\sigma = \tan^{-1}\left(\frac{h_r - h_s}{L_G \cdot \gamma_{0.01}}\right)\ degrees$$

Fuzzy Set Associated with Unit Commitment

After identifying the fuzzy variables associated with the unit commitment, the fuzzy set defining these variables are selected and normalized. The sets defining the dB state factor (DSF) are as follows:
DSF(dB) ={high, middle, weak}.
The Voltage Factor (VF) is stated by the following sets.
VF(v) = {low, strong}.
The Phase QPSK Factor (PQF) is defined by the following sets.
PQF = {right, near, outside}
The Production output is given by,
PO = {rain, somerain, clearsky}

Membership Function

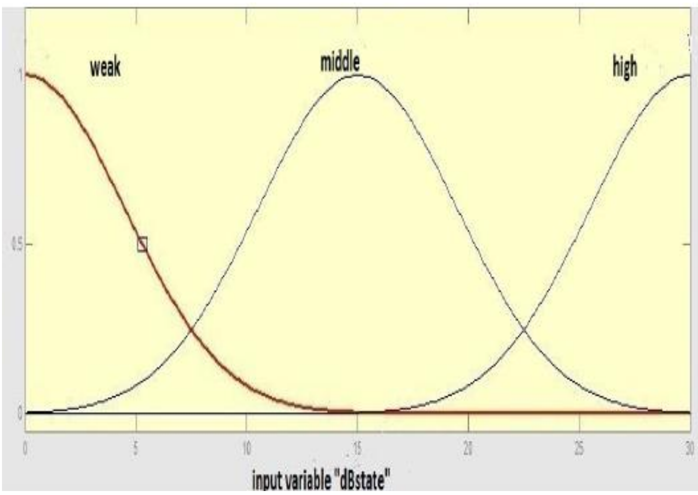

Fig. 2 Membership function of dB state factor

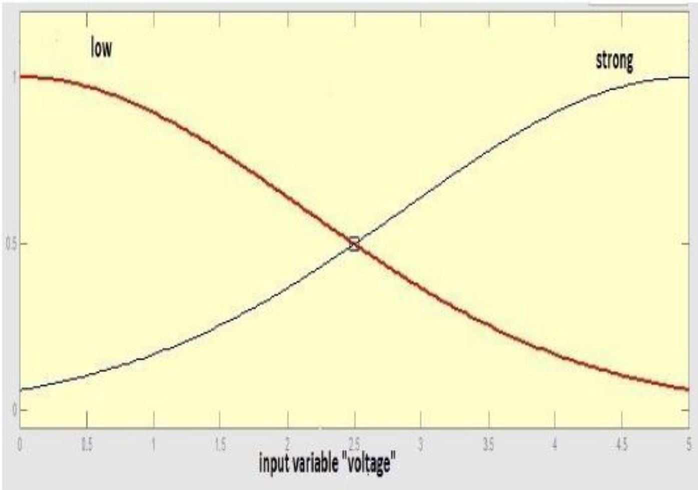

Fig. 3 Membership function of Voltage Factor

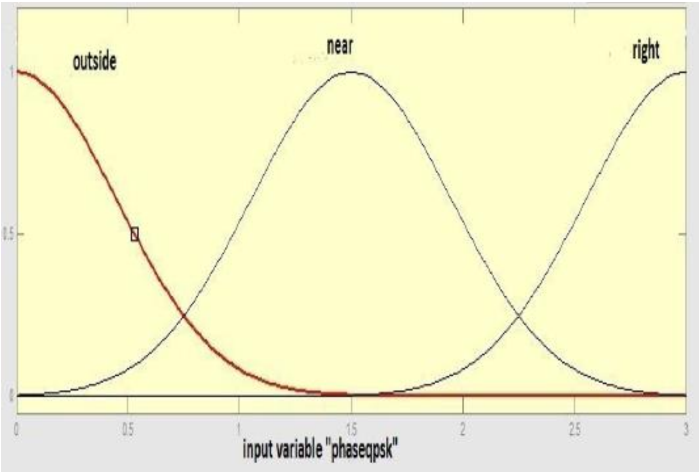

Fig. 4 Membership function of Phase QPSK Factor

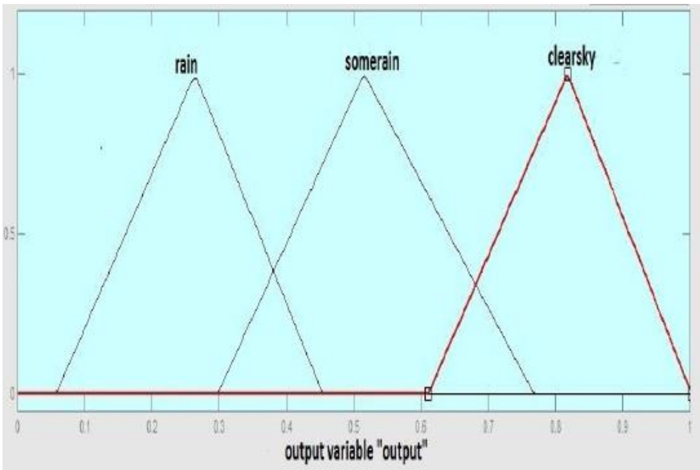

Fig. 5 Membership function of Production output

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Based on the aforementioned fuzzy set, the membership functions are chosen for each fuzzy input and output variable . A shape membership function is chosen for all the fuzzy variables.

Fuzzy If – Then Rules
The fuzzy-logic–based approach ,decisions are made by forming a series of rules that relate the input variables to the output variable using If-Then statement. The if (condition) is an antecedent to the Then (consequence) of each rule. Each rule in general can be represented in the following manner:

If (antecedent) Then (consequence)

dB state factor , Voltage Factor and Phase QPSK Factor are considered as input variables and production output is treated as the output variable. This relation between the input variables and the output variable is given as;
Production output = {dB state factor} or {Voltage Factor} or {Phase QPSK Factor}

In fuzzy set notation this is written as

$$PO = DSF \cup VF \cup PQF$$

We use above notation, fuzzy rules are written to associate fuzzy input variables with the fuzzy output variable. Based on these relationships and with reference to Figs., a total of 18 rules can be composed (since there are 3 subsets for dB State Factor, 2 subset for Voltage Factor and 3 subset for Phase QPSK Factor (3*2*3=18)).

For instance, rule 3 can be written as follows:

Rule 1: If (dB State Factor is high) or (Voltage Factor is strong) or (Phase QPSK Factor is right) then (Production Output is clear sky).

Rule 2: If (dB State Factor is middle) or (Phase QPSK Factor is near) then (Production output is some rain).

Rule 3: If (dB State Factor is weak) or (Voltage Factor is low) or (Phase QPSK Factor is outside) then (Product Output is clear rain).
In similar manner total 18 rules can be formed.

Defuzzification Process
Defuzzification is final step in process fuzzy logic based. One of the most commonly used methods of defuzzification is the centroid or gravity method. Using this method, the production cost is obtained as follows:

$$\text{Production output} = \frac{\sum_{i=1}^{n} \mu(PO)i * POi}{\sum_{i=1}^{n} \mu(PO)i}$$

where
$\mu(PO)i$ is the membership value of the clipped output
POi is the quantitative value of the clipped output
n is the number of the point corresponding to quantitative value of the output.

SIGNAL TO NOISE RATIO MODIFICATION

SNR is a measure of signal strength for satellite signal relative to attenuations and background noise. Signal attenuations caused by rain, gaseous, cloud, fog and scintillation attenuations limit satellite's QoS links and system availability that operate at frequencies above Ku-band. Several factors such as power, modulation, etc, can perform an immense role in improving SNR and in maximizing system throughput and availability of the link. The entire system can be modeled as below.

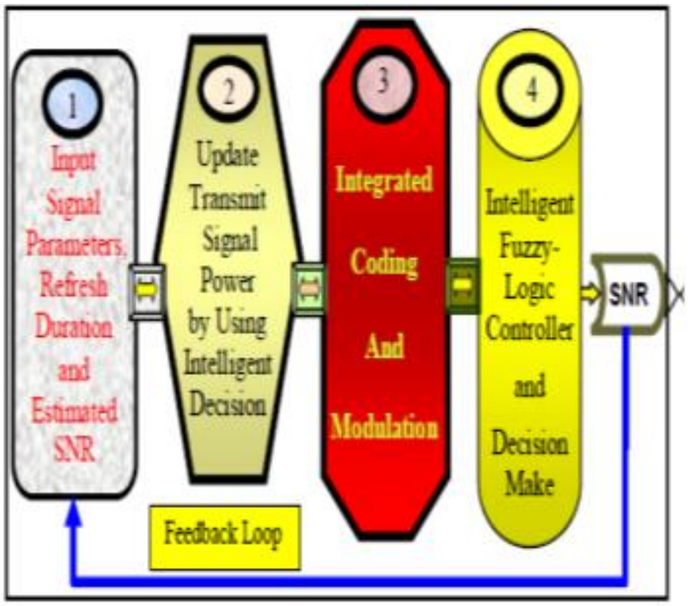

Fig 6.Intelligent Weather aware Scheme for Satellite Network.

By controlling rain attenuation factor that supply the fuzzy logic mechanism, to allow better estimates for satellite networking parameters such as link and queuing characteristics. These derived parameters adaptively adjusting signal power, coding, modulation, and would enable the proposed system to maintain SNR by transmission rate under unpredictable forecast. Intelligent systems are employed in the control of satellite systems to improve signal to noise ratio (SNR) by using predicted RAs and SNR factors under extreme signal-weather conditions by adjusting signal power, modulation and coding schemes. Using these scheme, BER(Bit error rate) will be reduced.
By definition,

Es (symbol energy) = C.Ts
= C / Rs,

transmission rate Rs (symbol/sec) is inversely equivalent to Ts (symbol duration) = 1/Rs Es / N0: Can be used to determine the bit error rate of a digital transmission scheme or visa versa. Fig 6. illustrates a manner for changing parameters of the communication system in order to overcome the deteriorating effect of atmospheric impairments, and to increase reliability of the data transmitted throughout the channel. In the first stage, the system holds input signal parameters such as frame size, propagation angle, etc. and SNR estimated values that were compared against threshold level, in a single database. In the last stage, the system will compromise among different SNR achieved outputs and make decision based on the intelligent fuzzy logic controller according to available parameters and requirements. The given feedback will keep looping until a satisfactory value is reached. Thus, this system can also change data rate, frame size, frequency, etc. in order to adjust SNR in cases such as unpredicted bad weather condition by using refresh duration that is located in the first stage. Fig. 7 and Fig. 8 compared the outputs of SNR ranges before and after modification respectively. Where SNR used to fall between (-51 ~ -28) dB, for power transmits from (-98 ~ -88) dB, and was transformed after intelligent decision mechanism to fall within modulation and coding boundaries of allowable used database. The adjusted output for SNR ranges from (-1.5 ~ 22) dB, (-48 ~ -38) dB for transmitted power, and (0 ~ 13.0) mm/hr for unchanged rainfall rate in both results. Note that, there is a limit of increasing transmits power up to around –30 dB.

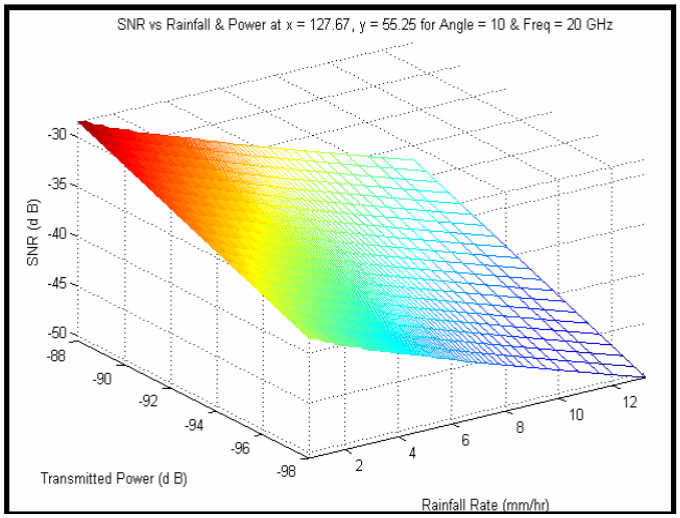

Fig 7. Output SNR at Yellowknife Station

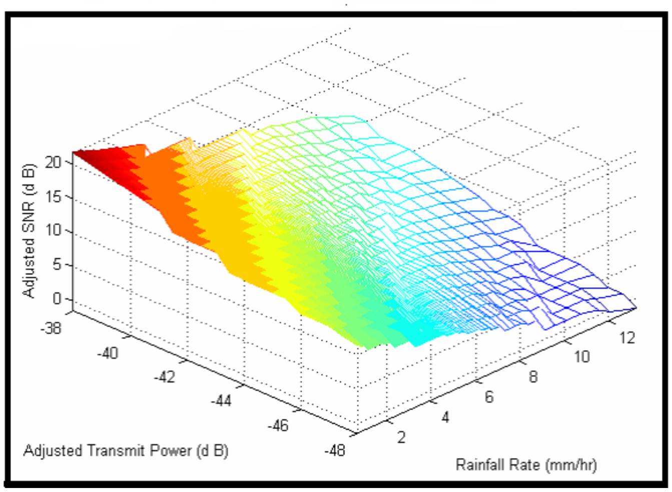

Fig 8. Output adjusted SNR at Yellowknife Station

Once this value has been reached, Mod/Cod selection should match in order to adjust SNR . Consequently, Fig. 7, Fig. 8 and Table 1 show throughput enhancements for satellite systems. They also create a robust system by allowing designers to work with flexible ranges by applying various combinations of modulation, coding and transmit power for any unpredicted weather conditions

Table 1. Forward Link Modes and Performance for $\theta = 8°$ and $f = 19$ GHz

Modulation	LDPC Code Identifier	E_S/N_0[dB] Measured and Estimated	Transmit Power [dB]	Rainfall Rate [mm/hr]
QPSK	1/4	-1.5	-52	10.32
QPSK	1/3	-0.3	-51	10.03
QPSK	2/5	0.7	-49	11.16
QPSK	1/2	1.3	-50	9.31
QPSK	3/5	3.2	-47	10.63
QPSK	2/3	3.8	-48	8.91
QPSK	3/4	4.8	-49	6.50
QPSK	4/5	5.3	-46	9.29
QPSK	5/6	5.8	-45	9.68
QPSK	8/9	6.8	-44	9.97
8PSK	3/5	6.4	-42	12.71
8PSK	2/3	7.3	-43	10.48
8PSK	3/4	8.6	-41	11.25
8PSK	5/6	10.0	-40	10.86
8PSK	8/9	11.4	-39	10.42
16PSK	2/3	9.6	-42	8.97
16PSK	3/4	10.9	-38	11.94
16PSK	4/5	11.8	-40	8.79
16PSK	5/6	12.4	-37	11.49
16PSK	8/9	13.7	-35	12.25

CONCLUSION

This research indicated that the frequency of rain directly affected to QoS on the satellite system. The outcome is key factor in diagnosing, adjusting and improving satellite signal power, modulation and coding schemes, monitored and controlled altogether by a powerful and efficient intelligent based attenuation countermeasure system. However this research finds method to improve signal can receive the better signal when rain attenuation by use of fuzzy logic in the system. In simulation use of fuzzy logic method can improve receive bit in system more than regular system.

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