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Performance Evaluation of Modulation Schemes Used for Digital Microwave Communication Systems

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***Abstract*– This study examines the performance of the modulation schemes used in digital microwave communication systems. The bit error rate (BER) performance of different digital modulation schemes is evaluated without taking bandwidth into account, to determine the BER suitable for the energy per bit to noise power spectral density ratio (E_o/N_o) through additive white Gaussian noise (AWGN) channel. The results showed that the higher order modulation rates are able to offer much faster data rates and higher levels of spectral efficiency for the microwave communications system, but are considerably less resilient to noise and interference.**

***Index Terms*– Digital Modulation, Bit Error Rate, Energy Per Bit To Noise Power Spectral Density, Receive Signal Level, Additive White Gaussian Noise Channel and Link Budget**

I. INTRODUCTION

THE electrical signals used in communication are of two types - the analogue signals that continuously vary with time and the digital signals which are not continuous. Many of these signals have frequency spectra that are not suitable for direct transmission especially when atmosphere is used as the transmission channel. In such a case, the frequency spectra of the signal may be translated by modulating high frequency carrier wave with the signal, hence modulation may be defined as the process by which some parameter of a high frequency signal termed the carrier, is varied in accordance with the signal to be transmitted [1].

Any frequency within the electromagnetic spectrum associated with radio wave propagation is referred as Radio Frequency (RF). Microwave is a kind of electromagnetic wave. In a broad sense, the microwave frequency range is from 300 MHz to 300 GHz. But in microwave communication, the frequency range is generally from 3 GHz to 30 GHz. According to the characteristics of microwave propagation, microwave can be considered as plane wave. The plane wave has no electric field and magnetic field longitudinal components along the propagation direction. The electric field and magnetic field components are vertical to the propagation direction. Therefore, it is called transverse electromagnetic wave and TEM wave for short [2]. The inherent reliability and cost effectiveness of microwave technology have been given a dominant role in connecting mobile radio base stations (RBS) and base station controllers (BSC).

Microwave communication refers to the communication that use microwave as carrier while digital microwave communication refers to the microwave communication that adopts digital modulation. Digital microwave communication transmits digital information in atmosphere through microwave or radio frequency (RF). The baseband signal is modulated to intermediate frequency (IF) first. Then the intermediate frequency is converted into the microwave frequency.

The electromagnetic field theory is the basis on which the microwave communication theory is developed.

From Fig. 1, the digital baseband signal is the unmodulated digital signal. The baseband signal cannot be directly transmitted over microwave radio channels and must be converted into carrier signal for microwave transmission.

II. BACKGROUND THEORY

Different digital modulation schemes are used in microwave transmission, equation 1.0 indicates a digital baseband signal being converted into a digital frequency band signal.

$$A*Cos(W_c*t + \varphi) \quad 1.0$$

Where; A = Amplitude
W_c = Frequency
φ = Phase

ASK: Amplitude Shift Keying. Use the digital baseband signal to change the carrier amplitude (A). W_c and φ remain unchanged.

FSK: Frequency Shift Keying. Use the digital baseband signal to change the carrier frequency (W_c). A and φ remain unchanged.

PSK: Phase Shift Keying. Use the digital baseband signal to change the carrier phase (φ). W_c and A remain unchanged.

QAM: Quadrature Amplitude Modulation. Use the digital baseband signal to change the carrier phase (φ) and amplitude (A). W_c remains unchanged.

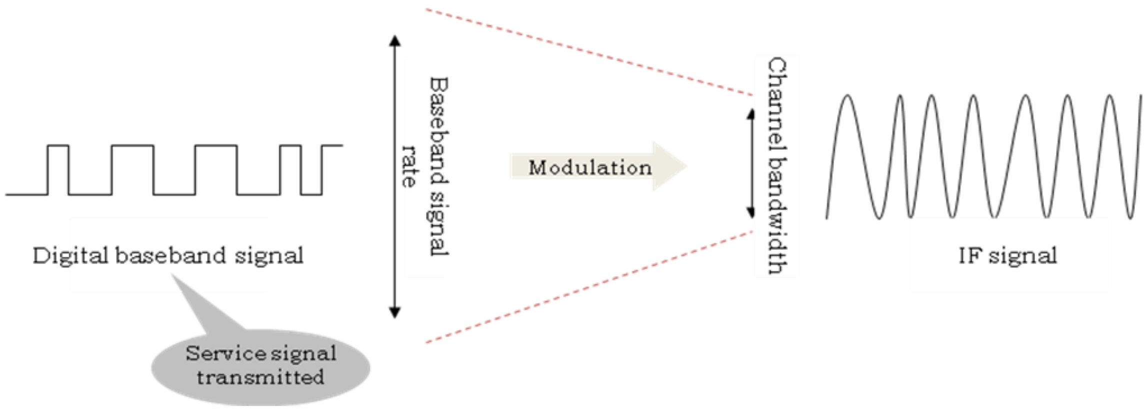

Fig. 1: Digital Microwave Modulation

In digital microwave link design, the link budget which is a calculation involving the gain and loss factors associated with the antennas, transmitters, transmission lines and propagation environment, to determine the maximum distance at which a transmitter and receiver can successfully operate, the system gain depends on the modulation scheme used (2PSK, 4PSK, 8PSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM) and on the design of the radio. The gains from the antenna at each end are added to the system gain (larger antennas provide a higher gain).

The free space loss of the radio signal is subtracted. The longer the link the higher the loss, these calculations give the fade margin. In most cases since the same duplex radio setup is applied to both stations the calculation of the received signal level is independent of direction.

Receive Signal Level (RSL)

$$RSL = P_o - L_{ctx} + G_{atx} - L_{crx} + G_{atx} - FSL \qquad 1.1$$

Link feasibility formula

$$RSL \geq Rx \text{ (receiver sensitivity threshold)} \qquad 1.2$$

Where; P_o = output power of the transmitter (dBm)
L_{ctx}, L_{crx} = Loss (cable, connectors, branching unit) between transmitter/receiver and antenna (dB)
G_{atx} = gain of transmitter/receiver antenna (dBi)
FSL = free space loss (dB)
Free-space loss - when the transmitter and receiver have a clear, unobstructed line-of-sight (LOS).

$$L_{fsl} = 92.45 + 20\log(f) + 20\log(d) \quad [dB] \qquad 1.3$$

where f = frequency (GHz)
d = LOS range between antennas (km)

In digital systems E_b/N_0, meaning energy per bit per noise spectral density ratio is used. E_b/N_0 can be related to bit error rate (BER) given the modulation type in question. For digital systems, the noise level of interest is in only 1 Hz of bandwidth using the notation N_0, the noise level in a 1-Hz bandwidth [3].

$$N_0 = -204 \text{ dBW} + NF_{dB} \qquad 1.3$$

Where; NF_{dB} = Noise figure
Noise figure simply tells us how much noise has been added to a signal while passing through a device in question.
E_b is the energy per bit. E_b can be stated as follows:

$$E_b = RSL - 10\log(\text{bit rate}) \qquad 1.4$$

Where; RSL = Receive Signal Level
The receive signal level (RSL) is the power level entering the first active stage of the receiver.
Formula for E_b/N_0 can now be developed as:

$$E_b/N_0 = RSL_{dBW} - 10\log(\text{bit rate}) - (-204 \text{ dBW} + NF_{dB}) \qquad 1.5$$

Simplifying, we obtain

$$E_b/N_0 = RSL_{dBW} - 10\log(\text{bit rate}) + 204 \text{ dBW} - NF_{dB} \qquad 1.6$$

III. METHODOLOGY

The method used in this work is based on the received signal equation,

$$r(t) = c(t) \text{ X } s(t) + n(t) \qquad 1.7$$

where; r(t) = received signal
c(t) = fading channel
s(t) = transmitted signal
n(t) = noise

Generally the signal to noise ratio is decided by the noise since the signal power usually is restricted. To consider this, the transmitted power of the signal is multiplied by fading channel. In result, the direct received signal power can be compare instantaneously with noise, which allows us to put BER in a fading or AWGN channel.

Modulation Techniques	SNR (dB)	Number of bits/symbol
QPSK	SNR<17	2
16-QAM	17≤SNR≤23	4
64-QAM	SNR>23	8

Table 1.0: Modulation schemes decision levels and number of bits/symbol

Table 1.0 gives us two things, the level for which the modulation should be switched, and the number of bits per symbol which will be used to calculate the spectral efficiency for the modulation schemes [4].

The BER performance for three modulation schemes which are QPSK, 16 QAM and 64 QAM are taken. Modulation scheme 128 QAM is an ideal state which is not used practically.

MATLAB simulation is taken over a range of information bit E_b/N_o values for each modulation scheme. Then the BER results for each E_b/N_o value is collected and the results is visualized in figure 2.0.

IV. RESULT AND DISCUSSION

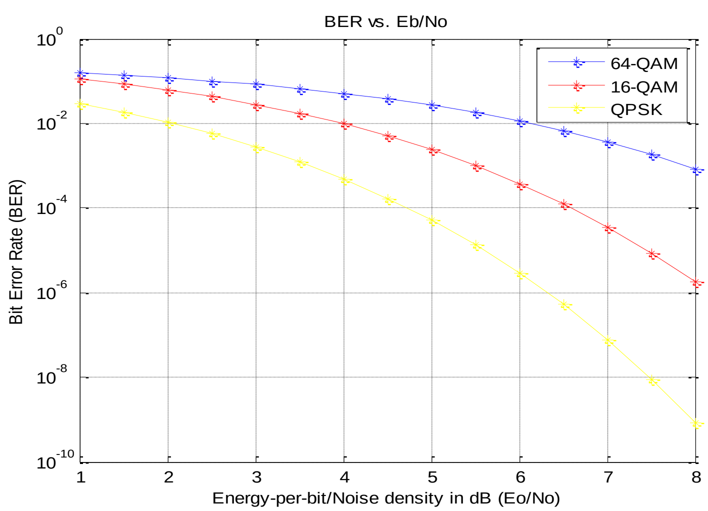

Fig. 2.0: BER performances versus E_o/N_o for AWGN channel

Figure 2.0 illustrates the probability of error for different modulation schemes for different SNR values. Now, considering that the minimum BER level is to be 10^{-3}, and dropped the 128-QAM as it is not practically used in normal situations. The system will try to maintain a BER less than 10^{-3} with the best possible spectrally efficient scheme. In this way, there is need to set the spectral efficiency as number of bits on a fixed transmission symbols. While operating at BER of 10^{-3} no modulation scheme will provide preferred SNR level below 10dB. So, it will be good to select the more robust QPSK which gives us SNR performance between 10dB and 17dB. The 16QAM system can get the better spectral efficiency which includes among 17dB and 23dB. For SNR greater than 23dB, 64QAM will provide maximum spectral efficiency for required BER performance. 64QAM will be able to carry more bits of information per symbol.

V. CONCLUSION

This study has shown the performance of different modulation schemes associated with digital microwave transmission. The study has shown that any modulation scheme use in microwave transmission system has impact on the spectral efficiency for the required BER performance. By selecting a higher order format of QAM, the data rate of a link can be increased. While higher order modulation rates are able to offer much faster data rates and higher levels of spectral efficiency for the microwave radio communications system, this comes at a price. The higher order modulation schemes are considerably less resilient to noise and interference.

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