Adaptive Power Control for Terrestrial Microwave Communication Link in Tropical Region

Tharek Abdul Rahman and Toh Chee Leng

Wireless Communication Research Laboratory, Dept. of Communication Engineering, Fac. of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

***Abstract*--Propagation of microwave signal above 10GHz involves not only free space path loss but also other attenuation due to atmospheric phenomena. In tropical region, the high rain rate has become a serious degradation factor for microwave communication system. Rain attenuation reduces the receiving signal in microwave link, thus decrease the signal-to-noise ratio (SNR) and increase the bit-error-rate (BER). Adaptive power control is proposed as a solution for maintaining the received signal above the threshold level corresponding to the BER. This paper presents the system level design of a 26GHz microwave communication transceiver with adaptive power control to overcome the rain attenuation problem. The transceiver system design and simulation are done with communication system design software.**

***Keywords*--Adaptive power control, microwave communication link, rain attenuation, transceiver.**

I. INTRODUCTION

WIRELESS communication is moving forward to multimedia application. In the coming years, Third Generation Mobile Communication (3G) is expected to be launched in Malaysia, where its implementation will require existing mobile communication system to support higher data rate and user capacity. As an integrated part of mobile communication, more point-to-point microwave communication link will be needed. The point-to-point microwave system that links the base station with mobile switching center will require higher reliability performance.

For microwave communication system that operates in frequency above 10 GHz, the rain will cause significant attenuation to the signal, thus increase the bit-error-rate (BER). In tropical region with high rain rate (exceeds 145mm/h for 0.01 percentage of time), rain attenuation has been identified as the main degradation factor for link performance. Instead of decreasing the propagation distance by using more microwave link, specific solution, which is more economical to be implemented and able to maintain the flexibility of the link, should be provided.

The signal-to-noise ratio (SNR) level is the concerned parameter at receiver. It should always exceed the threshold level for desired BER performance. To increase the operation margin, the transmitting power should be increased or the noise level of the receiver should be reduced.

Adaptive Power Control will be designed for compensating the rain attenuation. However, when operating in non-raining condition, the transmit power remains in low level to avoid interference. The microwave link performance will be able to maintain at both raining and non-raining situations, thus increase the reliability as what will be required for 3G communication system.

The system components that used in tropical region microwave communication systems need to meet higher performance requirements. By using communication system simulation software, all the system parameters can be determined and optimized for the required performance.

II. SYSTEM REQUIREMENTS FOR OPERATING IN TROPICAL REGION

System requirements for operating in tropical region are different with in non-tropical region. It needs to take into the account of rain attenuation. A radio unit is used as a reference for determining the improvement required. It is AirMAN2000™ from Netro Corporation for 26GHz communication link. The maximum output transmitted power (P_{TX}) available from transmitter radio unit is +20dBm. The receiver threshold level is −89dBm for BER 10^{-6}. The transmitting and receiving antennas are 0.6 meter parabolic antennas with gain (G_{TX} and G_{RX}) 41dB. The modem unit associated with it uses 4QAM modulation, with data rate 2x2.048Mbps.

The system is designed for 5km propagation distance with 0.01 percentage of unavailability. The free space path loss for 5km propagation distance, L_{FS} is

$$
\begin{aligned}
L_{FS} &= 32.45 + 20\cdot \mathrm{Log}_{10} f + 20\cdot \mathrm{Log}_{10} d \qquad (1)\\
&= 32.45 + 20\cdot \mathrm{Log}_{10} 26000 + 20\cdot \mathrm{Log}_{10} 5\\
&= 134.73 \text{ dB}
\end{aligned}
$$

f = operating frequency in MHz
d= distance between transmitter and receiver in km

Previous research from Wireless Communication Research

Laboratory Universiti Teknologi Malaysia [8] has measured the rain attenuation for 26GHz microwave signal in Malaysia. The measurement result shows that the rain attenuation that needs to be considered for 0.01 percentage of time is 73.7dB for 5 km propagation distance. The signal arrives at receiver for 73.7dB rain attenuation in propagation link is −106.4dBm. Since the signal is lower than the −89dBm, threshold level, the system cannot be used for 0.01 percentage of unavailability in 5km distance. 17.4dB additional operating margin is required.

For reducing the noise power level in the receiver, low noise components are used in the front-end. Placing an additional LNA will reduce the noise figure of the whole system. However, simulation on receiver with additional LNA shows that the noise level is not significantly reduced [9]. Previous simulation also shows that the SNR during rain can be maintained by increasing transmitted power level. Therefore, adaptive power control is designed as an integrated part for existing radio unit.

III. Adaptive Power Control

Adaptive power control is installed in the front-end of transmitter as in Fig. 1. It consists of programmable attenuator, attenuator driver and amplifier. The amplifier amplifies the signal to the maximum level that needs to be transmitted. Programmable attenuator is placed after the amplifier to adapt the transmit power automatically by referring to the control signal. Attenuator driver produces control signal to programmable attenuator according to the sampled automatic gain control (AGC) from radio unit and the settings from PC. When the sampled AGC level indicates that the received power level falls below threshold level, the attenuator driver will process relevant control signal for the gain margin need to be compensated to the system. Programmable attenuator will decrease the attenuation as to increase the transmit power level. Fig. 2 shows the block diagram of adaptive power control.

Adaptive power control can also be distributed along the system. Fig. 3 is an adaptive power control transmitter with 2 automatic gain control in different part of the system.

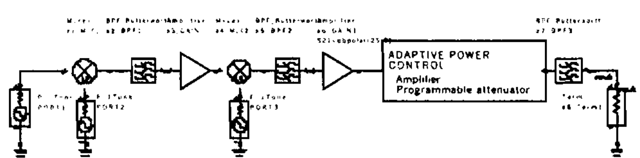

Fig. 1. Adaptive power control transmitter

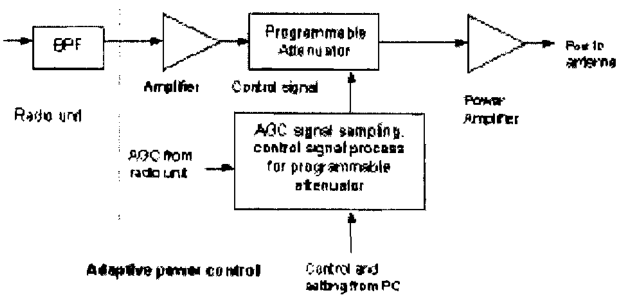

Fig. 2. Adaptive power control

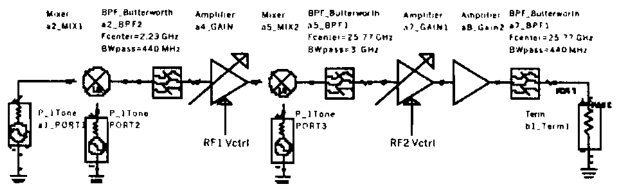

Fig. 3. Adaptive power control transmitter with 2 automatic gain control amplifiers in different part of the system

Noise figure is not a critical factor in transmitter design. Limitation of implementing additional gain to the transmitter is the compression point of the components. System in Fig. 2 is easier to be implemented because the gain compression problem only involves the front-end amplifier. System in Fig. 3 requires all components with higher compression point. However, system in Fig. 3 will provide better result. When the unwanted sideband and other frequency components are filtered out, more signal power will occur at the main spectrum when it reaches the next amplification stage.

IV. Simulation of 26GHz Microwave Communication Link

Simulation for the radio unit is performed with Agilent ADS Communication Systems Designer. First, typical system is simulated for observing the effect of rain attenuation to the received power level. Then, the adaptive power control is designed to compensate the loss due to rain attenuation. Finally, the improved system is simulated. The simulation analyzes the effectiveness of the system, in terms of gain budget, noise figure, power transmitted and power received.

A. *Transmitter Subsystem Simulation*

1) *Without adaptive power control*

The transmitter subsystem simulation determines the gain budget and compression point of the system. The simulation schematic shown in Fig. 4 is transmitter without adaptive power control. The IF input level is −20dBm. The budget gain of the whole system is determined at the output of front-end band pass filter (input of component Term1). The result

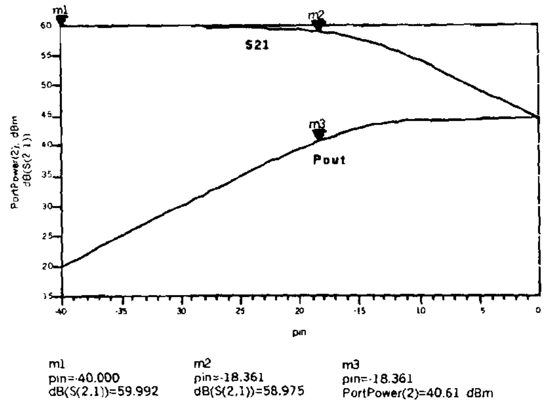

Fig. 7. Compression characteristic for transmitter with adaptive power control.

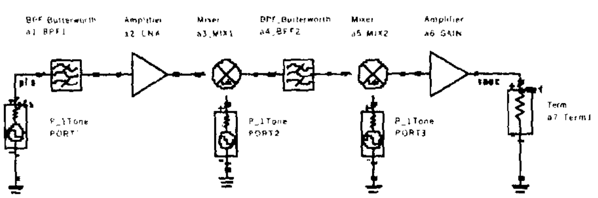

Fig. 8. Simulation schematic for receiver system

TABLE III
RECEIVER BUDGET NOISE FIGURE BUDGET AT INPUT OF EACH COMPONENT

Component	rcvr_nfbud freq=140000000.000
a1_BPF1	0.000
a2_LNA	1.000
a3_MIX1	3.000
a4_BPF2	3.033
a5_MIX2	3.035
a6_GAIN	3.161
a7_Term1	3.407
PORT1	0.000
PORT2	0.000
PORT3	0.000

C. Microwave Communication Link Simulation

1) Without adaptive power control

Simulation of the microwave link includes transmitter, receiver, free space propagation path and rain attenuation. The transmit power is +20dBm. 41dB gain parabolic antenna is used in the microwave link. Propagation distance is 5km. The rain attenuation is increased from 0dB to 74dB with 2dB step.

TABLE IV
RECEIVER GAIN BUDGET AT INPUT OF EACH COMPONENT

Component	rcvr_bgain freq=140000000.000
a1_BPF1	-3.709E-6
a2_LNA	1.000
a3_MIX1	24.000
a4_BPF2	18.000
a5_MIX2	17.000
a6_GAIN	11.000
a7_Term1	36.000
PORT1	-3.709E-6
PORT2	116.000
PORT3	116.000

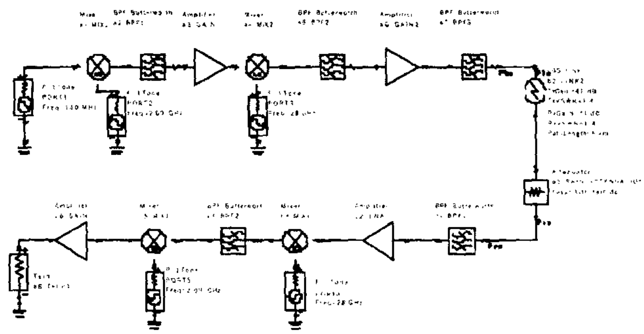

Fig. 9. Transceiver simulation schematic without adaptive power

The simulation schematic is shown in Fig. 9. The simulation result in Table V is the power transmitted and the power received when the rain attenuation exist along the propagation path.

The result in the Table V shows that the received signal cannot be maintained above the threshold level when the rain attenuation exceeds 56dB. The transmit power needs to be increased with adaptive power control to ensure the received power sufficient to maintain BER 10^{-6} for 0.01 percentage of time.

2) With adaptive power control

For transmitter with adaptive power control, the maximum budget gain is the transmitter gain that provides maximum output power when the attenuation of programmable attenuator is minimum.

For simulation of microwave link with adaptive power control and rain attenuation, rain attenuation is set from 58dB to 74dB with 1dB step. The adaptive gain and the received power level corresponds to the rain attenuation are analyzed. Fig. 10 is the simulation schematic. Simulation result in Fig. 11 shows the adaptive gain, power received with and without adaptive power control.

The received power for typical transceiver is -106.65dBm when rain attenuation is 74dB. However, when adaptive of budget gain and compression characteristic simulation is showed in Table I and Fig. 5.

The simulation result shows that the budget gain of the transmitter is 40dB, which provides output up to +20dBm output power (table 4). The 1dB compression is at input power of −17dBm and output power of +22dBm (Fig. 5).

2) With adaptive power control

When adaptive power control is integrated into the system, the compression point might be the limitation for the system whether can amplify the transmit signal without distortion. The compression will likely happen when the transmit power is maximum at the front-end amplifier.

In the simulation, the signal input to the front-end amplifier is increased to the highest power level that will be transmitted by an additional amplifier. The output power from the transmitter is 40dBm now. Fig. 6 is the simulation schematic. Table II is the simulation result for gain budget and Fig. 7 is the compression characteristic of the transmitter.

The result shows that the budget gain of the transmitter is 60dB, which provides output up to +40dBm output power (table 4). The 1dB compression is at input power −18dBm and output power +40.61dBm (Fig. 7).

TABLE I.
TRANSMITTER GAIN BUDGET AT INPUT OF EACH COMPONENT FOR TRANSMITTER WITHOUT ADAPTIVE POWER CONTROL

Component	tx_bud_gain
	freq=25770000000.000
a1_MIX1	9.643E-16
a2_BPF2	-7.000
a3_GAIN1	7.000
a4_MIX2	23.000
a5_BPF1	16.000
a6_GAIN2	16.000
a7_BPF1	40.000
a8_Term1	40.000
PORT1	9.643E-16
PORT2	26.000
PORT3	26.000

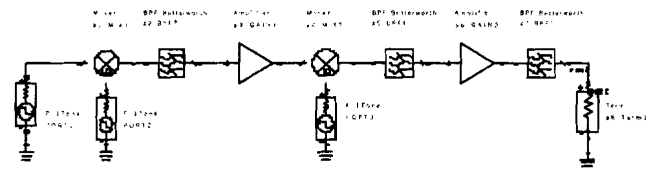

Fig. 4. Simulation schematic for typical transmitter system

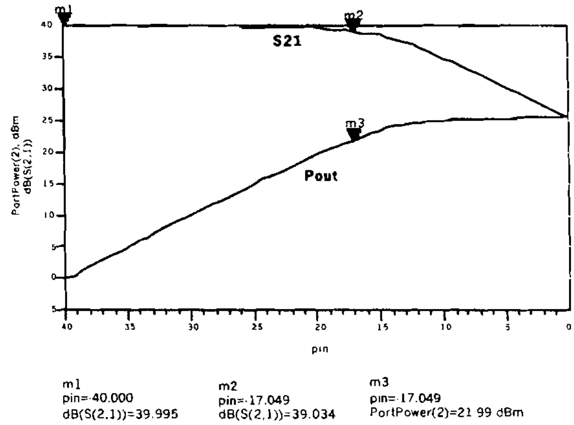

Fig. 5. Compression characteristic of transmitter without adaptive power control.

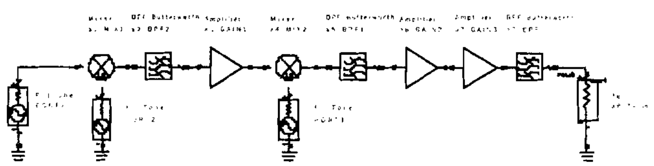

Fig. 6. Simulation schematic for transmitter with adaptive power control

TABLE II
GAIN BUDGET AT INPUT OF EACH COMPONENT FOR TRANSMITTER WITH ADAPTIVE POWER CONTROL

Component	tx_bud_gain
	freq=25770000000.000
a1_MIX1	9.643E-16
a2_BPF2	-7.000
a3_GAIN1	-7.000
a4_MIX2	23.000
a5_BPF1	16.000
a6_GAIN2	16.000
a7_GAIN3	36.000
a8_BPF1	60.000
a9_Term1	60.000
PORT1	-9.643E-16
PORT2	27.000
PORT3	27.000

B. Receiver Subsystem Simulation

Receiver subsystem simulation simulates the noise figure, gain budget and SNR at the input of every component in the transmitter. The simulation schematic is shown in figure 8. Table III and Table IV is the simulated noise figure and gain budget for receiver.

From Table III and Table IV, the noise figure and gain budget of the receiver are 3.407dB and 36dB. This receiver will be integrated in the microwave link simulation.

power control is integrated into the simulation, the received power can be maintained at minimum of −86.65dBm. The maximum adapted gain is 20dB to compensate the rain fade margin.

TABLE V.
POWER TRANSMITTED AND POWER RECEIVED FOR COMMUNICATION LINK WITHOUT ADAPTIVE POWER CONTROL

Attn_rain	spec_Ptx	spec_Prx
	...25770000000.000	..25770000000.000
10.000	21.339	-42.650
12.000	21.339	-44.650
14.000	21.339	-46 650
16.000	21.339	-48.650
18.000	21.339	-50.650
20.000	21.339	-52.650
22.000	21.339	-54.650
24.000	21.339	-56.650
26.000	21 339	58.650
28.000	21.339	-60.650
30.000	21 339	62.650
32.000	21.339	-64.650
34.000	21.339	-66.650
36.000	21 339	68 650
38.000	21.339	-70.650
40.000	21.339	72 650
42 000	21.339	-74 650
44.000	21 339	76.650
46.000	21.339	78.650
48.000	21.339	-80.650
50.000	21.339	-82.650
52.000	21.339	84.650
54.000	21 339	-86.650
56.000	21 339	88.650
58.000	21 339	90.650
60.000	21 339	92.650
62.000	21 339	94 650
64.000	21 339	-96.650
66.000	21 339	98.650
68.000	21 339	-100.650
70.000	21.339	102.650
72.000	21.339	-104.650
74 000	21.339	106.650

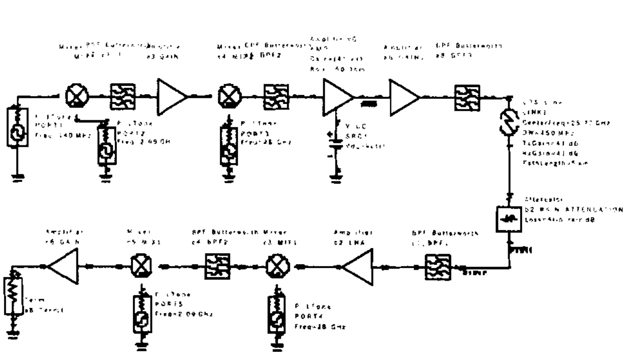

Fig. 10. Transceiver simulation schematic with adaptive power control.

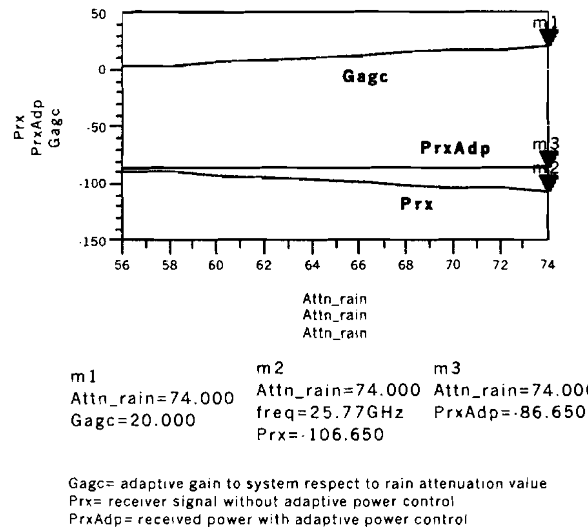

Fig. 11. Adaptive gain, power received with and without adaptive power control.

V. CONCLUSION AND FUTURE WORK

System level design for radio unit of microwave link is performed with Agilent ADS Communication System Designer. The simulations are budget analysis for transmitter and receiver, and microwave link analysis for with and without adaptive power control. The typical system simulation determines the additional power required for 0.01 percentage of time. The system simulation shows that transmitter with adaptive power control can maintain the received power above threshold level for operating in tropical region.

As future work, other performance studies, such as the intermodulation and interference will also be considered in the system simulation. Digital modulation and demodulation system will be included in the transceiver simulation and the BER performance will be available through simulation. Prototype of adaptive power control will also be developed. The prototype will consist of programmable attenuator, amplifier and attenuator driver circuit as the hardware component with interface and control software.

REFERENCES

[1] Dr. Kamilo Feher, "Wireless Digital Communications Modulation and Spread Spectrum Applications", *Prentice Hall*, New Jersey, 1995.
[2] Ericsson Microwave System, "Mini-link E Technical Description", *Ericsson Microwave System*, Sweden, pp. 29-38, 1997.
[3] Ferdo Ivanel, "Terrestrial Digital Microwaves Communication", *Artech House*, MA, 1989.
[4] Ken Hansen, Alexis Nogueras, "Receiver RF Design Consideration for Wireless Communications Systems", *IEEE*, 1996.
[5] Lawrence Dunleavy, Paul Flikkema, Thomas Weller, Anbuselvan Kuppusamy, E.Benabe, "Characterization and Simulation of a 915

MHz Receiver", Applied Microwave & Wireless, *Noble Publishing Corporation*, GA, July 1999.

[6] Netro The Wireless ATM Company, "AirMAN2000™ Operation and Installation Manual", *Netro Corporation*, California, pp. 12-28, 1997.

[7] Peter Vizmuller, "RF Design Guide, System, Circuits, and Equations", *Artech House*, MA, 1995.

[8] Rafiqul M.I. & Tharek A.R., "One-year Measurement of Rain Attenuation of Microwave Signal at 23GHz, 26GHz and 38GHz in Malaysia", The 4th CDMA International Conference (CIC'99), Seoul, Korea, September 8-11,1999.

[9] Tharek Abdul Rahman and Toh Chee Leng, "Performance Improvement of Terrestrial Microwave Communication Transceiver System for Tropical Region Application", Conference on Electrical, Electronics, Communication and Information CECI'2001, Indonesia, March 7-8, 2001.

[10] Theodore S. Rappaport, "Wireless Communications Principles and Practice", *Prentice Hall*, New Jersey.

[11] Ulrich L. Rohde, Jerry Whitaker, T.T.N Bucher, "Communication Receivers", Second Edition, *McGraw-Hill*, New York, 1984.