

Wireless PtP System in E-band for Gigabit Ethernet

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Abstract— In this paper, wireless PtP system in E-band (70/80GHz) for gigabit ethernet link was designed and fabricated. To two-way communication of FDD(frequency division duplexing), two types of transmitter/receiver were made. The conversion gains of transmitter were 7-12dB and 15-25dB respectively and P1dBs were both max 16dBm. The conversion gains of receiver were -6-0dB and 10-20dB respectively. Two PLOs were fabricated for 36.75GHz and 41.75GHz. The output powers were both 9dBm and phase noises at 100KHz offset were -103dBc/Hz and -102dBc/Hz respectively. OOK(On Off Keying) modulation was used in fabricated system. For OOK modulation, OOK modulator and demodulator were designed and fabricated. OOK modulator was made with RF mixer and OOK demodulator was made up of schottky diode and limiter amp. An demonstration for two-way communications was performed at indoor environment. It showed that this PtP system was well done in 10M distance with +5dBm output power and 20dB gain horn antenna.

Keywords— E-band, Point-to-Point, Gbps, OOK

I. INTRODUCTION

Recently, there has been a rapid growth of wireless communication, broadcasting, and internet. Gigabit Ethernet standard (GE) is now widespread and 10Gigabit Ethernet (10GE) standard has been available[1]. Higher data rate needs more cost for ethernet network. Wireless ethernet link is one of the solution to solve this cost problem. Wireless point-to-point(PtP) link can provide bridges for the gaps in the fiber network and extend the network in edge. Also, wireless PtP link can be used for high speed and low latency backbone for camera security applications, redundant network paths for mission-critical applications, temporary connection and disaster-recovery connection applications, and 3G/4G base station backhauls. Higher data rate needs more wide spectrum. But, there is no space to use in traditional radio frequencies. Using millimeter-wave band, Gigabit ethernet speed can be obtained easily. There are two major band for wireless PtP link. The one is WPAN band(57-64GHz) and the other is E-band(71-76GHz/81-86GHz). In the last few years, Korea, U.S., and Canada have opened 7 GHz of contiguous bandwidth (57-64 GHz) for unlicensed use. Japan has also opened 7 GHz bandwidth (59-64 GHz)[2]. U.S., Canada, and U.K. have opened 10GHz of 71-76GHz

and 81-86GHz for light licesed use. And Korea is considering for opening the band. Although WPAN band can be used for free in many contries, WPAN band is not suitable for wireless PtP link with long distance. Because WPAN band has higher propagation loss of oxygen absorption than E-band[3].

We desinged and fabricated the wireless PtP system which was working in 70GHz/80GHz and demonstrated two-way communcation with Gigabit ethernet standard.

II. DESIGN OF E-BAND SYSTEM

The block diagram of E-band wireless PtP system was shown in figure 1. 70/80GHz transceiver module consisted of OOK modulator/demodulator, Up-converter, Down-converter, 37GHz/42GHz PLOs and diplexer. Baseband module was composed of Gigabit ethernet controller, 8B/10B encoder, and 8B/10B decoder. Becasue FDD was used in this system, Tx path and Rx path were isolated with diplexer.

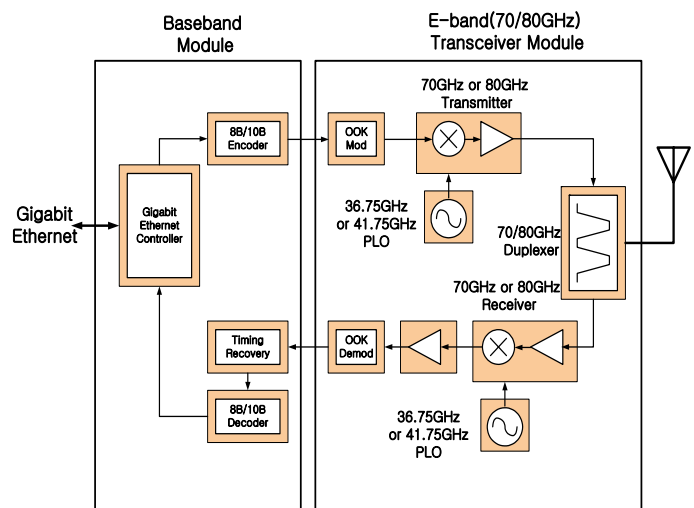


Figure 1. Block diagram of E-band wireless PtP Link system (only one side is shown in this Fig.)

With gigabit ethernet controller in Baseband module, E-band wireless PtP system was interfaced with Gigabit ethernet. After 8B/10B encoder, 1Gbps signal was encoded to 1.25Gbps signal.

was shown in figure 4. It showed that we could simply realize OOK modulator with only mixer and LO signal

The millimeter wave transmitter was composed of integrating multiple GaAs MMICs. Because we used OOK modulation, the operating bandwidth was over 2.5GHz for 1.25Gbps. So, we aimed to achieve a flat response over the wide bandwidth. The block diagram of designed transmitter was shown in figure 2. To operate Up-mixer, doubler was used in LO path. Although phase noise characteristic is degraded about 6dB if the signal is doubled, it is more easy and more cheap to make LO signal in around 40GHz than in around 70/80GHz.



Millimeter wave Receiver

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graph RL; RF[RF: 73.5GHz or 83.5GHz] --> LNA[Low Noise Amp & Drive Amp]; LNA --> Mixer((Mixer)); LO[LO: 36.75GHz or 41.75GHz] --> Doubler[Doubler]; Doubler --> Mixer; Mixer --> IF[IF: 8.75GHz ~ 11.25GHz];
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IF

8.75GHz ~ 11.25GHz

Mixer

Low Noise Amp & Drive Amp

RF

73.5GHz or 83.5GHz

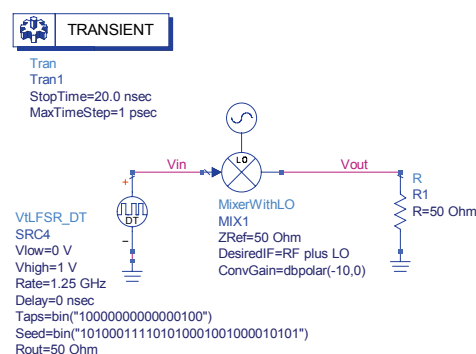
Doubler

LO

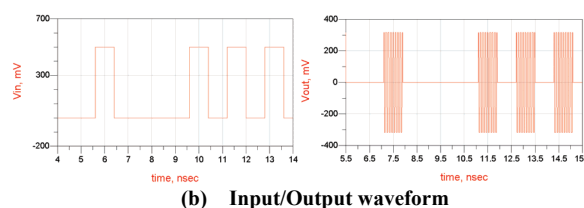
36.75GHz or 41.75GHz

Figure 3. Block diagram of Millimeter wave Receiver

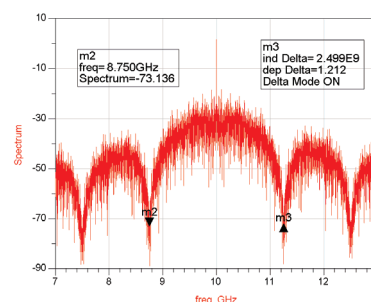
OOK modulator was easily made up of RF mixer and 10GHz VCO. The signal induced in IF port of mixer was multiplied with LO signal. When IF signal was “0”, there was no output signal. And when IF signal was “1”, A signal which was multiplied with IF signal (DC of some magnitude value) and LO signal(10GHz). A simple simulated results



(a) Simulation block diagram



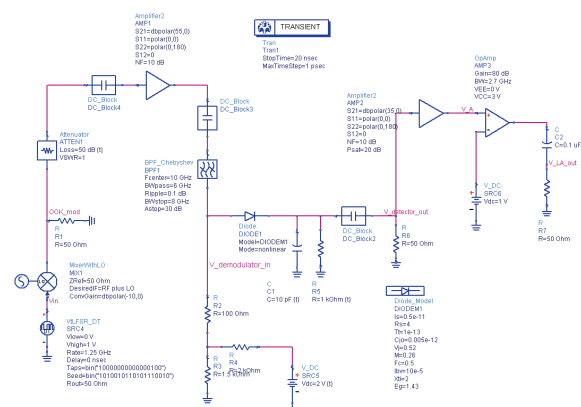
(b) **Input/Output waveform**



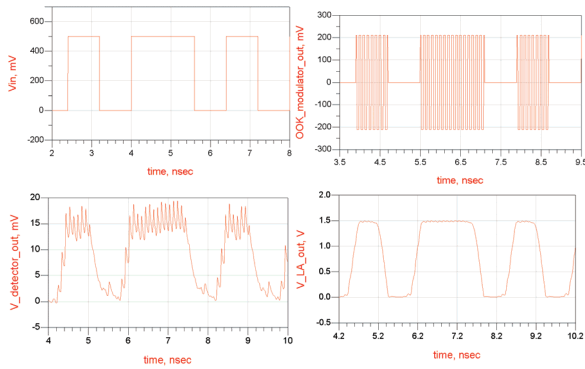
(c) **OOK output Spectrum**

Figure 4. Simulation for OOK Modulator

We made OOK demodulator with power detector and limiter Amplifier. Schottky diode was used for envelope detector. The simulation results was shown in figure 5.



(a) Circuit of OOK Demodulator



(b) Waveforms at each node
Figure 6. Simulation for OOK Demodulator

D. Design of PLOs

We used GaAs MMIC mixers in transceivers and each LO path of mixer had a doubler, so LO/2 oscillators were needed to operate millimeter wave transmitter/receiver.

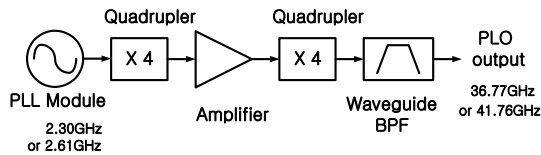


Figure 6. Block diagram of PLO Modules

The block diagram of PLO was shown in figure 6. We generated the fundamental LO signal with 2.3GHz/2.61GHz PLL module. And the fundamental signal was totally multiplied by 16 times with two quadruplers. Because the 16 times multiplied signal had many harmonics and spurious through quadruplers and amp, waveguide BPF was used at the end of PLO modules to remove these unwanted signals.

III. EXPERIMENTAL RESULTS

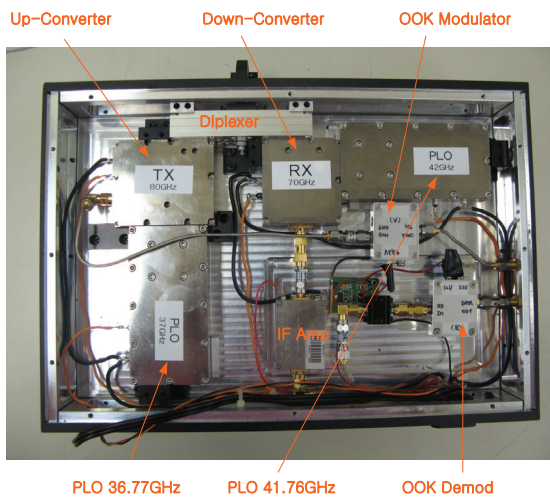


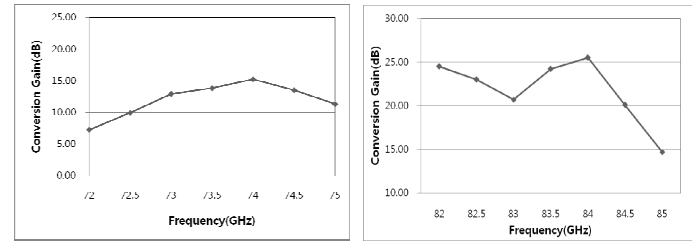
Figure 8. Photograph of E-band wireless PtP system

Implemented E-band wireless PtP system was shown in figure 7. Transmitter was for 80GHz and receiver was for

70GHz. The PLOs were connected to transceiver with waveguide port WR-28 and WR-12 was used for connection of transceiver-diplexer and diplexer-external antenna.

A. Millimeter wave transmitter

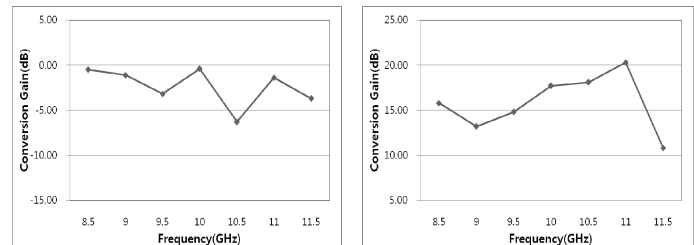
We fabricated two Millimeter wave transmitters for 70GHz and 80GHz. The measured conversion gains were shown in figure 7. The conversion gain of 70GHz transmitter was 7 ~ 12dB and P1dB of that was measured as max. 16dBm at 74GHz. And the conversion gain of 80GHz transmitter was 15 ~ 25dB and P1dB of that was measured as max 16dBm at 83.5GHz.



(a) 70GHz
Figure 7. Conversion Gain of 70GHz Transmitter

B. Millimeter wave Receiver

Two millimeter wave receivers for 70GHz and 80GHz were fabricated. The measured data of conversion gain were shown in figure 8. The conversion gain of 70GHz receiver was -6 ~ 0dB and that of 80GHz receiver was 10 ~ 20dB. The noise figure of receivers is expected around 10dB because the NF of used LNA GaAs chips was typically < 5dB and additional losses in front of LNAs such as insertion loss of diplexer, waveguide to microstrip transition loss and wirebonding loss was typically < 3dB.



(a) 70GHz
Figure 8. Conversion Gain of 70GHz Receiver

C. 36.77GHz and 41.76GHz PLOs

We fabricated 36.77GHz PLO and 41.76GHz PLO for frequency division duplexing. Because TX frequency and RX frequency were separated by 10GHz and each up/down converter needs LO/2 signal, the frequency interval of PLOs was 5GHz. The measured results of phase noise were shown in figure 9 and figure 10. The output power of 36.77GHz PLO was 9dBm and PN is -103dBc/Hz at 100kHz frequency offset. Also, the output power of 41.76GHz was 9dBm and PN is -102dBc/Hz at 100kHz frequency offset.

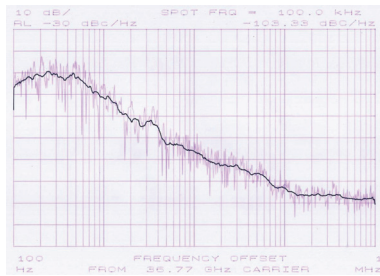


Figure 9. Phase Noise characteristic of 36.77GHz PLO

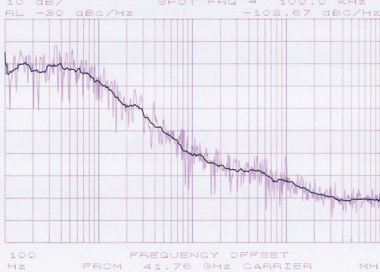
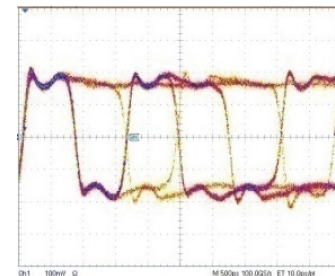


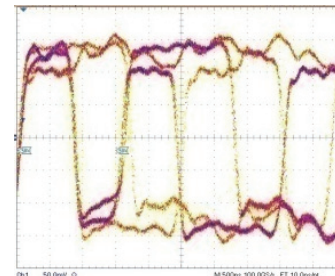
Figure 10. Phase Noise characteristic of 41.76GHz PLO

D. Measured Link Performance

A test-bed was built and tested in the indoor environment. The block diagram of the link measurement was shown in figure 11. Each notebook computer transmitted a video signal and received the video signal from the other laptop computer simultaneously through the Gigabit ethernet port. The test-bed link was installed with +5dBm Tx output power and 10M distance between two sites. And we used two horn antennas which has 20dB Gain for indoor measurement. The measured waveforms of OOK modulator input and OOK demodulator output were shown in figure 12. It showed that the link had no error in the 10M distance practically. Because this link operate well at 10M distance with 20dB Gain antenna, this link was expected to work well more than 1Km distance with 50dBi gain antenna at outdoor environment.



(a) OOK modulator input signal



(b) OOK demodulator Output signal

Figure 12. Measured waveforms of OOK modulator input and OOK demodulator output

IV. CONCLUSION

In this paper, wireless PtP system for gigabit ethernet link was designed and fabricated. Using OOK modulation, the PtP system was realized with simple structure. Although OOK modulation was not good modulation method at the point of frequency efficiency, there are plentifully available frequencies in 70/80GHz which is not used well and it is considered to open this E-band frequencies in Korea.

An demonstration for two-way communications of wireless link with gigabit ethernet network was performed at indoor environment. It showed that this PtP system was well done in 10M distance with +5dBm output power and 20dB gain horn antenna.

ACKNOWLEDGMENT

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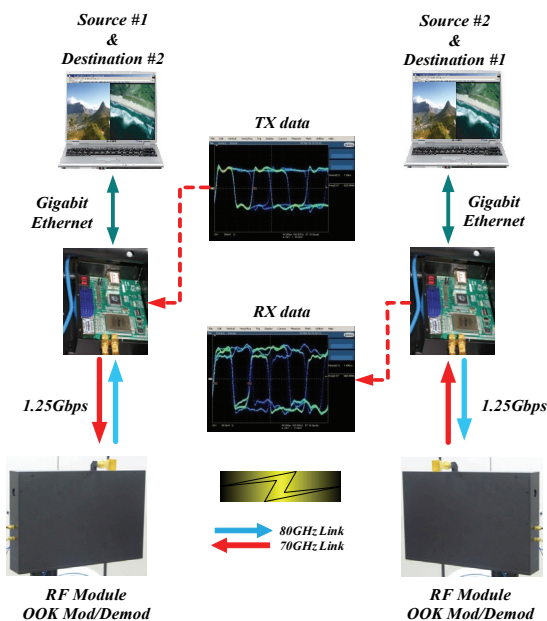


Figure 11. Block diagram of the link measurement