The Wireless Gigabit Ethernet Link Development at TMR&D

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Abstract: - TMR&D is developing a millimeter-wave point-to-point (PTP) Wireless Gigabit Ethernet Communication System. A 60 GHz Low Temperature Co-Fired Ceramics (LTCC) System-On-Package (SoP) Transceiver capable of gigabit data rate has been built and demonstrated with a size of 17.76 x 17.89 mm². A direct Amplitude-Shift Keying (ASK) modulation and demodulation scheme is adopted for the 60GHz-band transceiver. A BER of 1×10⁻¹² for data rate of 1.25 gigabit-per-second (Gbps) on 2.2 GHz bandwidth at 1.4 km was demonstrated. This paper reports a new PTP link that has been installed at TMR&D site to demonstrate wireless gigabit operation and performance of its key components. The link will operate at the 57.65-63.35 GHz band incorporating TMR&D’s designed millimeter-wave LTCC SoP RF Transceiver module. This LTCC SoP RF Transceiver is suitable for short-range wireless networking systems, security camera TV, video conferencing, streaming video like HDTV (high definition television) and wireless downloading systems for small power application.

Key-Words: - PTP link, Wireless gigabit, LTCC, SoP, RF Transceiver.

1 Introduction

Every new generation of wireless networks require more and more cell-sites that are closer and closer together combined with the fast growing demand for the capacity of the transmission links. Millimeter-wave (MMW) radio has recently attracted a great deal of interest from scientific world, industry, and global standardisation bodies due to a number of attractive features of MMW to provide multi-gigabit transmission rate. Wireless broadband access is attractive to operators because of its low construction cost, quick deployment, and flexibility in providing access to different services. It is expected that the MMW radios can find numerous indoor and outdoor applications in residential areas, offices, conference rooms, corridors, and libraries. It is suitable for in-home applications such as audio/video transmission, desktop connection, and support of portable devices while for the outdoor PTP MMW systems, connecting cell-sites at one kilometer distance or closer, it will offer a huge backhaul capacity.

The increasing demands for high-data rate communications have urged to develop MMW broadband wireless systems. Demands for high-speed multimedia data communications, such as a huge data file transmission and real-time high definition TV signal streaming, are markedly increasing, e.g., Gigabit Ethernet networks are now beginning to be widely used. Wireless transmission with 1Gbps and greater data rates is very attractive [1-2]. Carrier frequencies of wireless communications are also increasing from 2.4 GHz and 5 GHz to MMW such as 60 GHz bands [3]. For wireless communications applications, there has been a tremendous interest in utilising the 60 GHz band of frequency spectrum because of the unlicensed wide bandwidth available, maximisation of frequency reuse due to absorption by oxygen (O₂), and the short wavelength that allows very compact passive devices. However, commercial wireless PTP links started to become available in the 57-64 GHz band [4] and, in the 71-76 and 81-86 GHz bands. PTP links at 60 GHz can be used in wireless backhaul for mobile phone networks and able to provide up to 1 Gbps data rates. Sections of the 57-64 GHz band are available in many countries for unlicensed operation [5-6].

According to the International Telecommunication Union (ITU) Radio Regulations, the band 55.78–66 GHz, 71–76 GHz, 81–86 GHz, 92–94 GHz and 94.1–100 GHz are available for fixed and mobile services in all three ITU regions as depicted in Fig. 1. In Europe, the 59–66 GHz band has been allocated for mobile
services in general. In USA and Canada, the 57–64 GHz band is assigned as an unlicensed band. In Japan, the 59–64 GHz band has been made available on an unlicensed basis for millimeter wavelength image/data systems. In Korea, the 57–64 GHz band is assigned as an unlicensed band.

The usefulness of 60 GHz PTP links is limited however, because of additional propagation loss due to O₂ absorption at this band. The specific attenuation characteristic due to atmospheric O₂ of 10–15 dB/km makes the 60 GHz band unsuitable for long range (>2 km) communications so that it can be dedicated entirely to short range (<1 km) communications. For a short distances to be bridged in an indoor environment (<50m) the 10-15 dB/km attenuation has no significant impact [7].

Nowadays the 60 GHz band is considered to provide wireless broadband communication and the R&D for 60 GHz technology is very competitive in worldwide. The research and development for 60 GHz band is mandatory and urgent for national broadband system in future.

2 Wireless Gigabit Research at TMR&D

TMR&D has involved several years in microwave and MMW research. We started with the GaAs PHEMT MMIC design for several frequencies from 1–36 GHz. We managed to fabricate and tested using III-V semiconductor fabrication process facility. We developed numerous MMICs for a range of purposes including MMW satellite receiver, LMDS and MVDS applications. We also developed RF Transceiver for 3G Node B Base Station and IEEE 802.16d WiMAX Subscriber Station. These projects were funded by the Telekom Malaysia under Basic Research grant.

TMR&D is developing the PTP ultra broadband wireless link up to 1.25Gbps data rate on 2.2 GHz bandwidth (BW) using MMW 60GHz frequency band. This Wireless Gigabit Ethernet link has a function of a media converter to connect a fiber link to a full duplex wireless link seamlessly with 1.25 Gbps data rate for both directions. The data input and output interface is a 1000BASE-SX optical transceiver module with LC connectors. Millimeter waves can permit more densely packed communication links, thus it provides very efficient spectrum utilisation, and they can increase spectrum efficiency of communication transmissions within restricted frequency band.

We completed our first wireless gigabit ethernet system (PTP link demonstrator) incorporating with TMR&D’s LTCC SoP RF Transceiver module in December 2008. It operates at 57.65–63.35 GHz band and is suitable for ASK data rates of 1 Gbps and a maximum line of sight (LOS) path of 1.4 km for BER<10⁻¹². Outdoor propagation data has been collected since January 2009. Three sites have been tested at different locations, i.e. 0.8km, 0.9 and 1.4km. The V-band transceiver modules include GaAs MMICs together with the IF baseband in a metal housing attachment. The entire LTCC SoP RF Transceiver module was designed by TMR&D’s Researchers; the LTCC fabrication was outsourced to third party. The transmitter output is 10 dBm and the receiver NF is 8 dB. The antennas were commercially purchased, low-cost Cassegrain type with 48 dBi gain and beamwidth of 0.6 deg (Figure 2).

![Fig. 2: Millimetre wave links at the TMR&D Innovation Centre, Cyberjaya. A pre-commercial 60 GHz link](Image)

Table 1: TM MMW PTP Wireless Gigabit Ethernet Communication System Specification

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>57.55–63.35 GHz</td>
<td></td>
</tr>
<tr>
<td>Data Rate</td>
<td>1 Gbps</td>
<td></td>
</tr>
<tr>
<td>Maximum Line of Sight Path</td>
<td>1.4 km</td>
<td></td>
</tr>
<tr>
<td>Transmit Power</td>
<td>10 dBm</td>
<td></td>
</tr>
<tr>
<td>Receiver NF</td>
<td>8 dB</td>
<td></td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>48 dBi</td>
<td></td>
</tr>
<tr>
<td>Beam Width</td>
<td>0.6 deg</td>
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</tbody>
</table>

![Fig. 1: Worldwide 60 GHz Band Allocation](Image)
Table 1 shows the system specification of the TM MMW PTP Wireless Gigabit Ethernet Communication System. This system can be used as PTP link, and establishing high-speed backbone networks, such as backbone link or wireless backhaul. This system is also used for satellite, broadcasting and observation purposes. Figure 3 illustrates the PTP system suitable for applications which can serve high capacity PTP up to 1.25Gbps Wireless Gigabit Ethernet link. Thus, the outdoor units are optimised for Ethernet radio links or mobile communication backhauls.

Fig. 3: 60GHz PTP Wireless Gigabit Ethernet Link

This PTP system is the fastest wireless solutions for PTP wireless in IP network such as Fast and Gigabit Ethernet applications. The interconnection between two endpoints apart from last mile can be easily deployed and installed. Current solutions included voice, leased line or optical fibers are too expensive to configure, and it’s very difficult or impossible to transmit when high data rate is required. So, the performances of the links are usually limited.

This system can be deployed with full-duplex security systems, and it can be used for wireless link between buildings in downtown or campus area where higher speed is required. Backup link for optical fiber is easily installed when a system is needed to replaced. Therefore, services can continue seamlessly even though any problems are on the link path.

Other applications of 60 GHz are as below.

a. Wireless high-definition multimedia interface (HDMI). Uncompressed video can be wirelessly transmitted from a DVD player to a flat screen [8].

b. Fast up and download of high-definition movies. Users can download high-definition movies from a video kiosk onto their mobile device or at home can download a movie from their mobile device onto the computer.

c. Wireless docking station. A laptop computer can be wirelessly connected to the network, the display, an external drive, the printer, a digital camera etc.

3 Millimeter-Wave Front End

TMR&D's advanced ASK (Amplitude Shift Keying) transceiver module has the best quality and superior performance to transmit ultra high speed digital data in millimeter wave. The maximum data rate is 1.25Gbps on 2.2 GHz of bandwidth for Gigabit Ethernet applications. We have developed low-cost multi-chip modules (MCMs) based on the multilayer LTCC technologies; 60GHz-transmission lines (CPW, MSL, eMSL), BPFs, patch antennas, active modules (PA, LNA, multiplier (MTL), Tx, and Rx), and L-band LPFs. Utilising these technologies, we have developed 60 GHz-band broadband wireless transceiver namely MyTraX (LTCC SoP Transceiver). The block diagram shown in figure 4 includes the antenna, diplexer and ASK LTCC SoP Transceiver with the optical transceiver being connected.

Fig. 4: 60GHz Point-to-Point Transceiver block diagram

In this ASK LTCC SoP Transceiver module, it consists of receiver (Rx) and transmitter (Tx) block. This transceiver is based on the ASK modulation method. The ASK has a carrier wave which either switched ON or OFF. For the Rx block, it consists of low noise amplifier (LNA) block, demodulator and low pass filter (LPF) whereas for the Tx block, it consists of frequency doubler, modulator (Mixer) and power amplifier (PA).

At Rx block, the signal received coming from antenna is downconverted to Intermediate Frequency (IF) signals and then to the original signals via baseband. For Tx block, the IF signals from the baseband are fed to the Tx block and upconverted to 60 GHz band, then transmit through antenna (Figure 5).
TMR&D develops several kinds of LTCC (Low Temperature Co-Fired Ceramics) MMW modules in 60GHz band. These LTCC modules have superior RF performance so that the whole systems equipped with the module can operate more stable.

Using multi-layer LTCC based SoP technology, various research efforts have been made for compact SoP RF systems. For 1.25Gbps wireless Ethernet link, fabricated 60GHz Tx and Rx modules were downsized into 13.82 x 6.55 mm² (Figure 6) and 11.02 x 4.31 mm² (Figure 7), respectively. The integration of Tx and Rx will produce the LTCC SoP Transceiver with a size of 17.76 x 17.89 mm².

Figure 8 shows frequency response for the Tx output power with IF sweep from 10-1500 MHz and LO at 58.752 GHz. The peak output power for the ASK modulated 60GHz band signal is plotted versus frequency. The output power is 13dBm. There is no resonance and oscillation problems occur at Tx module. The measured frequency spectrum of the LTCC Tx module is shown in figure 9.

For high sensitivity of the Rx, low-noise and high-gain components should be chosen. The Rx IF output test is plotted versus frequency. The sweep frequency is from 10 MHz–1500 MHz. The IF output is marked at -1.33 dBm with input power at -40 dBm. There is no resonance and oscillation problems occur at Rx module. The Rx performance is shown in figure 10. The NRZ Eye-Pattern is shown at the IF output level with data rate of 1.25 Gbps.

Isolation for Tx and Rx position need to be considered as it is required to avoid any signal losses during transmitting. Isolation of 80 dBc is required between the Tx and Rx block.
Tx and Rx block is placed in the same area of the transceiver module, the isolation requirement should be satisfied. There is no resonance and oscillation problems occur at Transceiver (TxRx) module. Figure 11 shows the TxRx module test result and figure 12 shows the transceiver module in a metal housing.

![Fig. 11: LTCC SoP Transceiver module test result](image1)

![Fig. 12: LTCC SoP Transceiver module in a metal housing](image2)

### 4 Conclusion

MMW technologies are becoming important for the high data rate communications of the future and research efforts are placed to reduce the cost of MMW front ends. TMR&D has developed key components to make PTP Wireless Gigabit Ethernet Communication System possible. It is now integrating the RF LTCC components into a complete link demonstrator for pilot testbed to test Wireless Gigabit Ethernet link, streaming video like HDTV (high definition television) or TiVo systems and obtain outdoor propagation data. Again, the 60 GHz band is available unlicensed worldwide.

This 60 GHz technology can provide new businesses and business models such as corporations and wireless hot spots which may provide Gigabit Ethernet connectivity, as well as video, to its customers. One of the main applications of these radios is replacement of fiber at the last mile.

### References:


