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**SPECTRUM ASPECTS**  
**TECHNOLOGY ASPECTS**  
**GENERAL ASPECTS**

## Korea (Republic of)

### TECHNICAL FEASIBILITY OF IMT IN THE BANDS ABOVE 6 GHz

At the 14<sup>th</sup> meeting, ITU-R WP 5D has developed the matrix of frequency ranges and their perceived suitability for IMT, which is in the attachment to the SWG Meeting Report (Document [5D/196](#) Att. 4.16) for further discussion at its 15<sup>th</sup> meeting. Bands above 6 GHz were also described in the matrix with the following note:

*In fulfilling its responsibilities under WRC-15 Agenda item 1.1, WP 5D is also considering the suitability of frequency ranges above 6 GHz for IMT systems. WP 5D plans to report on the results of its considerations on the suitability of these bands to the 3rd meeting of the JTG 4-5-6-7. System characteristics for use in sharing studies in the bands above 6 GHz are also being developed.*

To assist the discussion on the suitability of frequency bands above 6 GHz for IMT systems, this contribution provides the feasibility of IMT systems in the bands above 6 GHz. Advances in semiconductor technologies has made mm-wave wireless systems feasible, and commercial products of 60 GHz Personal Area Networks (PAN) are available soon under the labels of WiGig. Channel measurement results in 28/38 GHz are provided to show feasibility of using the lower mm-wave bands for IMT system. Therefore it appears that the mm-wave frequencies can be used for IMT system in dense urban environments, even in non-line of sight (NLoS) conditions.

## Proposal

The Republic of Korea would like to propose the followings:

- 1) As an accompanying document of Korean contribution, “Suitable frequency ranges above 6 GHz regarding WRC-15 Agenda item 1.1”, this contribution should be referred when WP 5D develops suitable frequency ranges above 6 GHz in the aspects of feasibility of IMT system.
- 2) This contribution should be included as an annex to the working document towards new draft Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS].
- 3) SWG Vision should also consider this contribution in the aspect of future IMT technology.

**Attachment:** Semiconductor technology status and outdoor NLoS channel measurement results above 6 GHz bands

## ATTACHMENT

### **Semiconductor technology status and outdoor nlos channel measurement results above 6 GHz bands**

#### **1 Introduction**

Driven by unprecedented growth in the demand for mobile data, and with no signs of a slowdown, industry and academia alike are looking for solutions that go beyond what can be offered by finding fragments of 10 MHz here and there. In particular, there is interest in finding large contiguous chunks of bandwidths that can be used for addressing the traffic explosion problem in a more fundamental way. This in turn has spurred interest in investigating the suitability of utilizing a very wide continuous bandwidth in millimeter-wave (mm-wave) bands for mobile broadband access [1-4].

Advances in semiconductor technology have made mm-wave wireless systems feasible [5-9]. Commercial products in mm-wave bands are now readily available. Notable examples are products in the 60 GHz Band (for Personal Area Networks (PAN) are available soon under the labels of WiGig [10][11]), products in the 28 and 38 GHz band (for wireless backhaul) as well as products in the E-Band (71-76, 81-86 GHz).

While the availability of large chunks of bandwidths, some of which are already available for mobile communication purposes in some countries, is very attractive an important question that needs to be addressed is “How far the can mm-wave signals propagate in a mobile environment, particularly in non-line of sight (NLoS) conditions”. What is clear is that the transmission distance is directly affected by two factors – the power amplifier output and the radio propagation characteristics.

This document provides semiconductor technology status for mm-wave bands and channel measurement results in 28/38 GHz with an aim to show the feasibility of using the lower mm-wave bands for IMT system. The extensive investigations (in the form of channel measurements and field-validation) and in-depth study results show that the mm-wave frequencies can be used for IMT system even in dense urban NLoS environments.

#### **2 Semiconductor Technology**

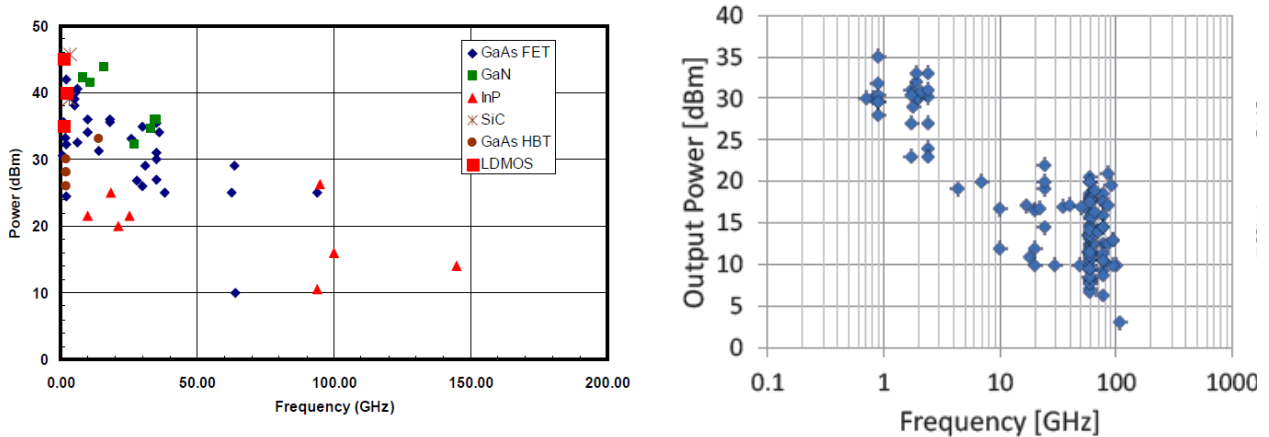
Mm-wave technologies have been developed in all areas including circuits, antennas and communication protocols, in order to exploit the large chunks of bandwidths in those frequency bands.

GaAs MMIC technologies are mature enough to have a dominant presence for power amplifiers (PAs), low noise amplifiers (LNAs), switches for digital attenuators and phase shifters, voltage controlled oscillators (VCOs) and passive components from a few GHz to 100 GHz already.

At the same time, recent technologies of Silicon-based CMOS (complementary metal oxide semiconductor) processes are capable of implementing integration systems-in-package including mixers, LNAs, PAs, and inter-frequency (IF) amplifiers in mm-wave bands, especially for 60 GHz commercialized products with the label of WiGig. Cost effective implementations of CMOS nano-process under 100 nm have facilitated the utilization of 60 GHz spectrum bands.

The Figure 1 shows the survey of output power for both MMIC-based PA and Silicon-based PA. PA output power level for the frequency range of 10 GHz to 100 GHz is relatively small compared to those for up to 10 GHz. However the effective isotropic radiated power (EIRP) can be boosted up with a beamforming technique that provides a high antenna gain by utilizing a large number of antenna elements.

FIGURE 1  
Left: Power MMIC Survey [14], Right: Silicon Power Amplifier Survey



#### Remark 1

The current semiconductor technologies are mature enough to implement the essential RF components for IMT system above 6 GHz bands.

### 3 Outdoor Radio Propagation

In order to investigate feasibility of mm-wave bands, channel measurements campaigns were conducted in various outdoor environments. This section shows measurement results in Univ. of Texas, Austin, New York Manhattan dense urban area, and Samsung Electronics, Suwon Campus, Korea. It was expected that since building surface wall is highly reflective in these bands, a radio communication link can be provided even through multiple NLoS paths. The measurement results confirm such expectation.

#### Campaign 1: University Campus (Univ. of Texas, Austin), 38 GHz [12][13]

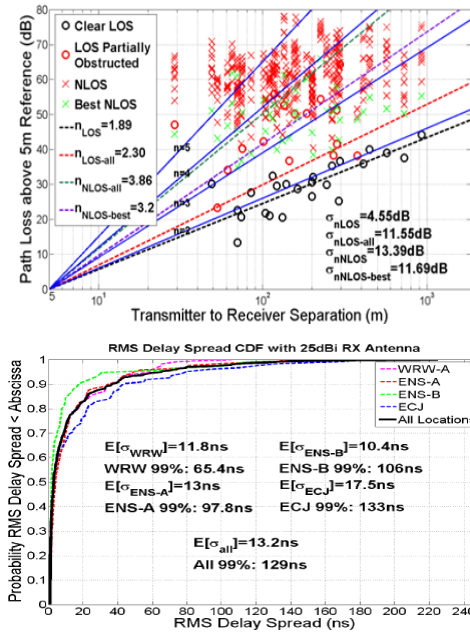
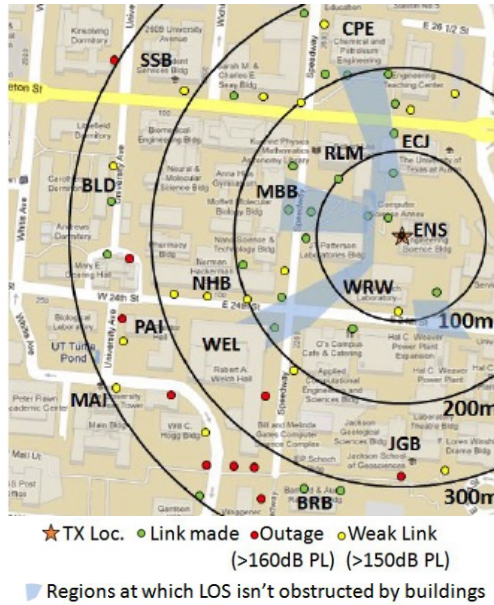
The first measurements were carried out at 38 GHz bands in Univ. of Texas, Austin campus. Channel bandwidth is 750 MHz, transmission power at amplifier 21 dBm, and horn antenna gain 25 dBi for both transmitter and receiver.

For the given environments, communication links between transmitter and receiver were successfully made with the distance of up to 200 meters. Note that even at many locations beyond 200 meters the links could be made. Pathloss exponents calculated from the beamforming-based measurements are 1.89~2.3 in line of sight (LoS) and 3.2~3.86 in NLoS links.

Note that the subscript of 'NLOS-all' in the figure means a statistical value obtained from all NLoS results while 'NLOS-best' does a value obtained from only the NLoS results for the best Tx and Rx beams matching. We can see that radio propagation characteristics can be made more favorable by matching the best Tx and Rx beams.

FIGURE 2

Left : Measurement sites in UT Austin campus, Right : Pathloss and RMS delay spread results



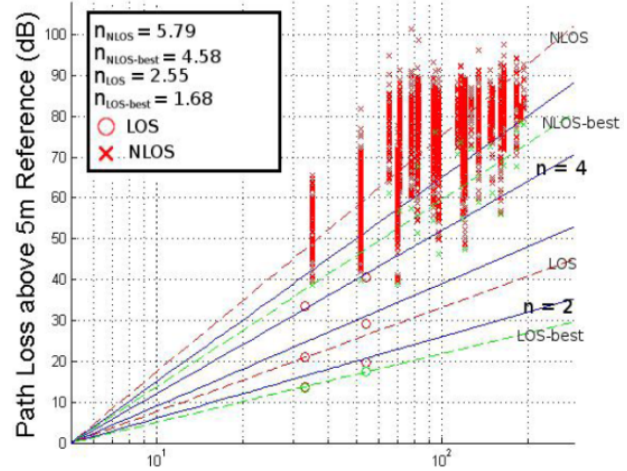
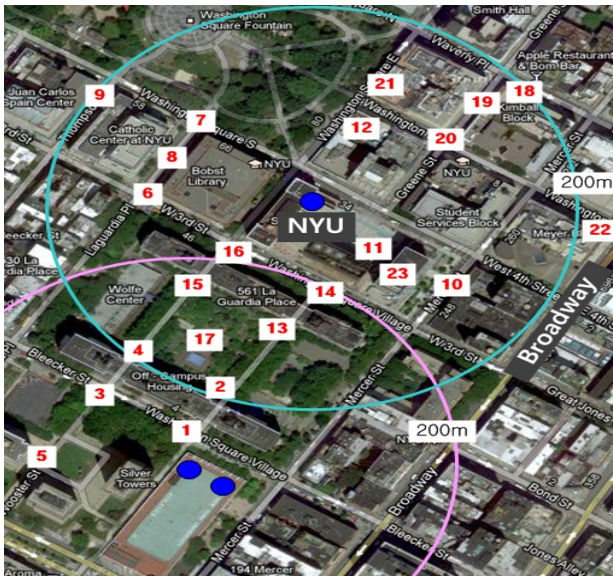
## Campaign 2: Dense Urban (New York, Manhattan), 28 GHz [14][15]

The second measurements were carried out at 28 GHz bands in Manhattan area. Channel bandwidth is 400 MHz, transmission power at amplifier 30 dBm, and horn antenna gain 24.5 dBi for both transmitter and receiver. Since these measurement environments are dense urban whose buildings have bricks and concrete walls, received signals are lower than at UT Austin campus. In these measurements, pathloss exponents are 1.68 in LOS and 4.58 in NLOS links, for the case of the best Tx and Rx beams matching.



FIGURE 3

Left: Measurement sites in Manhattan, Right: Pathloss results

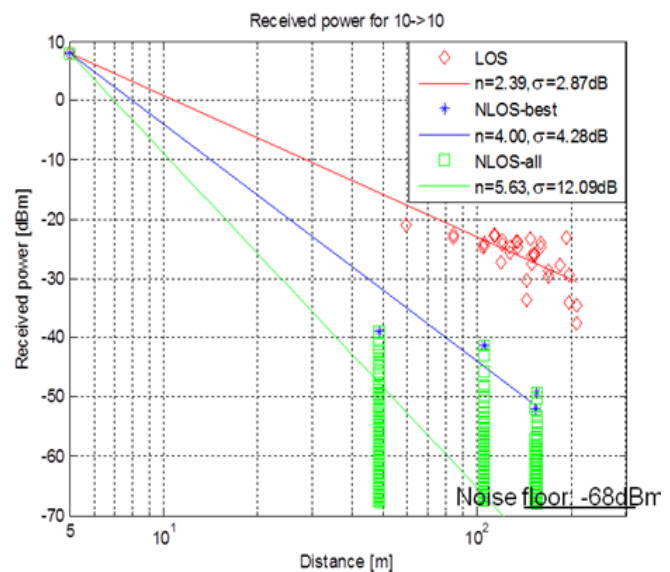
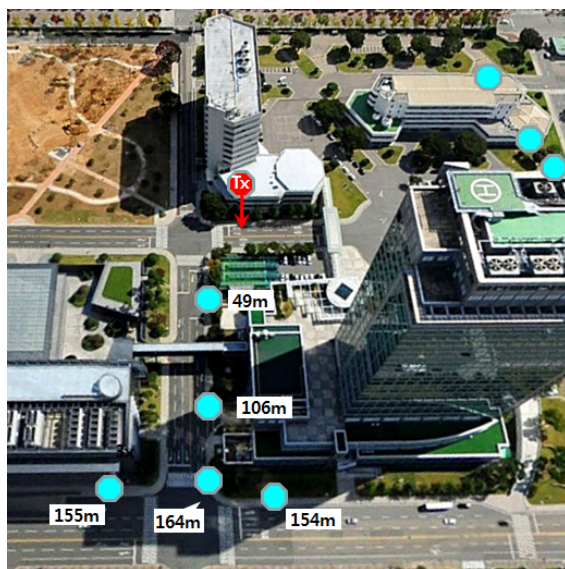


### Campaign 3: Research Campus (Samsung Electronics, Suwon Campus), 28 GHz [16]

The last measurements were performed at 28 GHz bands in Samsung Complex at Suwon, Korea. Channel bandwidth is 500 MHz, transmission power at amplifier 18 dBm, and horn antenna gain 24.4 dBi for both transmitter and receiver. These measurements show that pathloss exponents are 2.39 in LOS, and 4.0 in NLOS links for the case of the best Tx and Rx beams matching.

FIGURE 4

Left: Measurement sites of Samsung complex in Suwon, Korea, Right: Path loss exponent results



The results obtained from the three measurement campaigns in 28/38 GHz bands, show that pathloss exponent in NLoS link is between 3.2 and 4.58. This range is not much discrepant from that in the conventional IMT bands (i.e. 3.67~3.91) [17].

Lastly, we would like to note that although rain attenuation will place natural limits on radio propagation in mm-wave bands, it does not much affect within the range of our interest. In case of even heavy rain with rate of 60 mm/hr, rain attenuations for 200 meter distance are only 2 dB and 3 dB in 27 GHz and 38 GHz, respectively [18][19].

#### **Remark 2**

Mm-wave frequency is feasible for mobile broadband access, i.e. IMT, over 200 meters even in outdoor NLoS environments.

## **4 Concluding Remarks**

This document summarizes the technology status and the channel measurement results to provide evidence in support of feasibility of using mm-wave frequency for IMT systems.

From the standpoint of semiconductor technology, we have shown by pointing to credible references that both MMIC-based and silicon-based technologies for power amplifier are adequately developed and are now mature for implementation. To build trust in the propagation physics of the mm-wave channel, we shared the results, obtained through extensive measurement, which indicate that the observed/measured pathloss exponents are adequate for supporting a communication link over 200 meters even in outdoor NLoS environments.

Based on the measurements and the analysis of the state of the semiconductor industry, it appears feasible to utilize mm-wave frequencies for IMT systems.

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