筑波科技 6G 太赫茲全頻段介電常數量測系統

筑波科技 2021-02-17

無線通訊的應用，對「寬頻」的需求日益殷切，例如多媒體影音串流、車載物聯網、雲端運算、資料儲存及航太設備軍事雷達應用，而隨著頻率在毫米波(mmWave)的 5G 系統、超過 60 GHz 的車用、軍用、工業用雷達日益普及，5G、6G 技術驅動電子材料、組件、複合材料基板、PCB、IC 封裝、天線陣列等市場頻率升級需求。筑波科技深耕無線通訊測試領域 20 年，在 5G、mmWave、WiFi 6 到太赫茲(Terahertz，THz)技術應用有完整的測試方案。

針對操作頻率在 28G/39G/60G...100GHz 以上的超高頻段技術，如何設計適當電路及傳輸系統於不同場域應用，同時考量材料在超高頻時的 Lose 損失與干擾，已成為重要測試議題。高頻電子材料、元件特性，常以測介電常數(Dielectric Constant; Dk)配合向量網路分析儀(VNA)為主，可支援的頻率範圍約 100GHz，但常受限於 VNA 設備昂貴、高頻段不一、DUT 尺寸限定、治具不易製作、校正補償複雜、誤差大的問題。

業務開發經理蔡少軒表示，筑波科技與 Teraview 推廣的太赫茲時域頻譜儀(Terahertz Time- domain)已廣泛應用於全球科學與工業檢測。近期突破 6G 設計挑戰，開發新型介電常數檢測設備（DK6090 及 6G Solve)特色為：由飛秒(fs)雷射產生超短太赫茲脈衝訊號，以穿透及反射方式去獲得 30 GHz～3 THz 連續頻段之材料在時域及頻域的介電常數。此外在檢測過程中，系統將太赫茲訊號以非接觸方式操作，不需要治具，不僅省下過往檢測時之高額費用，同時也避免人為操作產生的誤差。

筑波科技先進研發部副總經理湯凱元亦指出，在邁向太赫茲的 6G 高頻時代，工程師更應該要掌握所使用的材料在這些超高頻段的特性，以確保系統特性與模擬階段時相同。筑波科技為台灣知名的無線通訊設備系統整合商，並在毫米波及太赫茲領域耕耘數年，目前與國內外的產學先進更有著多年研究開發測試經驗，可提供客戶最完整的服務。

＜照片：先進研發部副總經理湯凱元、商業開發經理蔡少軒＞

http://www.compotechasia.com/a/new_product/2021/0217/47139.html

Towards 6G – materials and system characterization tools

6G - Drivers

The exponential growth in demand for high bandwidth applications such as multimedia streaming, the Internet of Things and cloud computing has triggered the need for development of new technologies providing high-bandwidth, reliable links in wireless environments. This growth has recently been accelerated by thousands of schools and businesses world-wide that have moved their operations online as a result of COVID-19. High speed, wireless technology will increasingly be an important component of the solution to the problem of enhancing connectivity. To address this challenge, emerging 5G and planned 6G wireless platforms will use progressively higher frequencies in the 100 Gigahertz (GHz)-1 Terahertz (THz) range to achieve 1 Terabit (10^{12} bit) per second data rates required for broadband. By way of example, a recent report stated: "*It is not surprising that the THz band has become the promised land for the envisioned next generation of wireless communication—6G*".

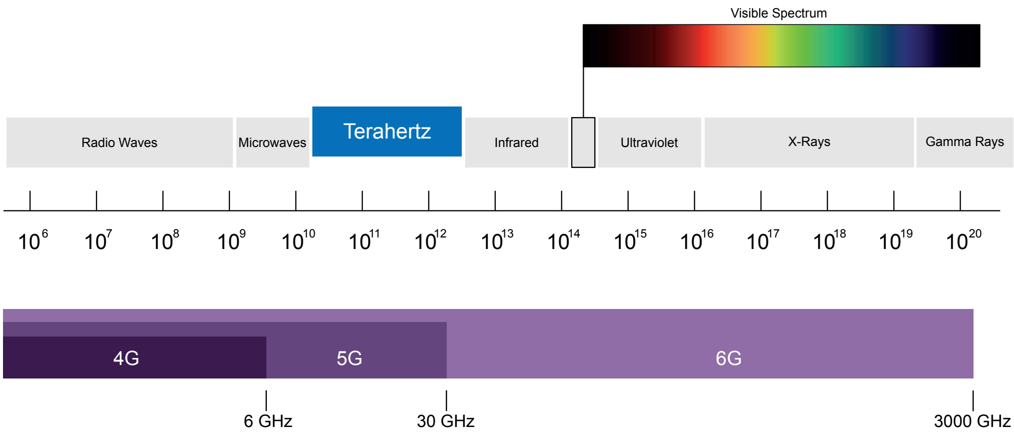

Figure 1
The location of the terahertz region in the EM spectrum

6G - Requirements

Development of devices, circuits, materials and wireless architectures at 6G frequencies requires test & measurement equipment operating in the terahertz region, and optimised for materials and system characterisation. Examples include:

- Understanding line-of-sight and non-line-of-sight propagation of 6G signals in different environmental conditions – e.g. in offices, outdoors, in large venues and under different ambient conditions.
- Measuring absorption and dispersion of a wide range of materials in these environments.
- Characterising the dielectric properties of materials in 6G devices & circuits, in intelligent beam steering platforms and in other aspects of 6G architecture.

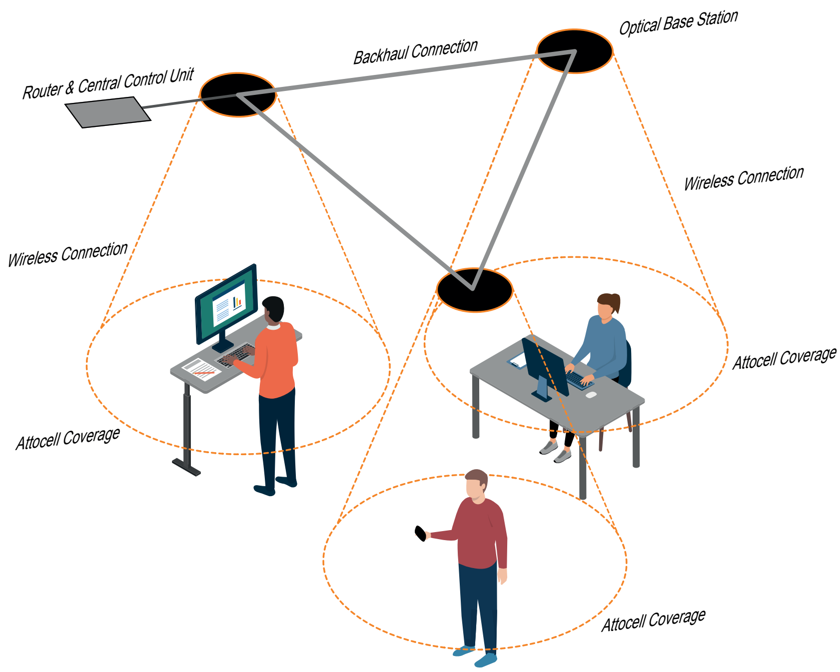

Figure 2
Office wireless links

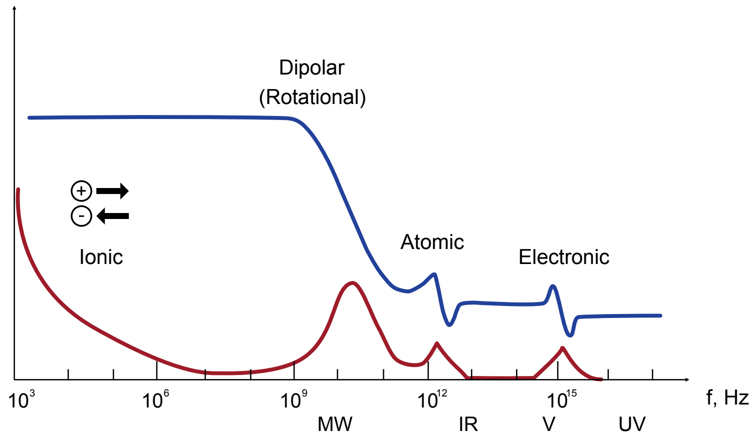

Figure 3
Dielectric mechanisms

Measurement Systems

Existing measurement systems based on vector network analysers (VNAs) provide continuous frequency coverage up to only ~100 GHz, and with limited (banded) coverage available thereafter. Such systems are prone to errors in measuring quantities related to the phase of data stitched between different frequency bands. They are also susceptible to errors arising from the size & geometries of small samples. For example, interference from standing waves means that VNAs are limited to the study of thick (> ~7 mm) samples only in many instances.

TeraView's **6GSolve** system, provides the solution to these challenges. Using time domain measurements that continuously and simultaneously cover frequencies in the ~30 GHz-3 THz band with high dynamic range, this technology has been successfully used to characterise the propagation properties of 6G signals and the dielectric properties of a wide range of materials. Moreover, samples as thin as < 100 μm can be characterised using the TeraPulse system.

The system provides information on the real and imaginary part of the dielectric constant and the loss tangent of materials in both transmission (e.g. S_{12}) or reflection (e.g. S_{11}) modes. It provides a non-contact measurement of the complex conductively of a variety of materials including graphene, Teflon® and various meta-materials.

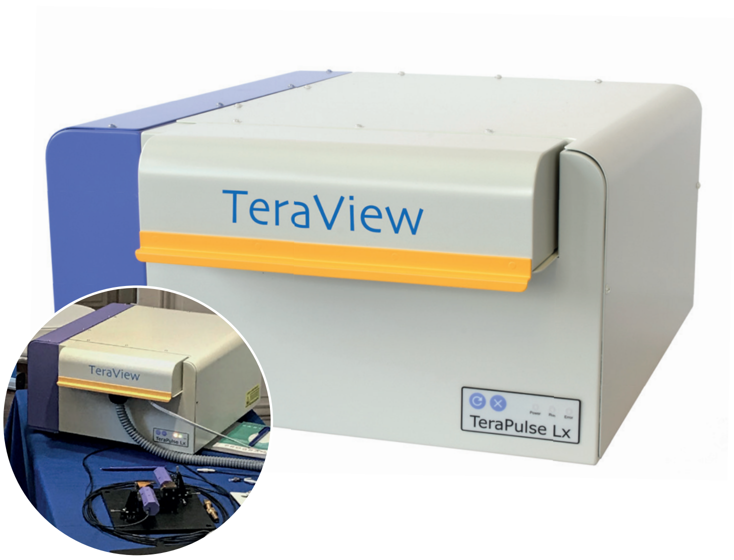

Figure 4
TeraPulse Lx Core Unit
used in 6GSolve

TeraView's unique position

As the pioneer in the commercialization and development of terahertz systems, TeraView is in a unique position to provide 6G test & measurement solutions and systems. TeraView has over 3 decades of experience working at 6G frequencies, resulting in over 100 peer reviewed publications, which is made available to our customers in terms of on-going, collaborative support and ventures. TeraView is interested in working directly with customers and collaborators to develop 6G devices, systems and architecture.

6GSolve – the test & measurement tool for 6G

6GSolve is a portable, modular system that gives the user both flexibility and expandability for test & measurement using free space terahertz pulses in the range 30 GHz - 3 THz. User-exchangeable plug and play modules allow for easy reconfiguration or extension of measurements. All systems include TeraView's patented laser-gated photo-conductive emitters & detectors, as well as patented optical delay line/single laser system so that any phase jitter is minimised through common mode rejection.

The system is driven by an ultra-fast (90 fs) laser supplied by Calmer Laser* to provide broad frequency coverage and unprecedented stability.

The system includes TeraView's TeraPulse core unit, which has an extensive track record of operation in the field in different applications. Transmission (S_{12}) and reflection (S_{11}) measurements in free space are supported via an easily configurable sample mount for the device under test (DUT), illustrated below in figure 5.

The system is designed to enable S_{12} and S_{11} measurements in a straight-forward manner once the DUT is mounted.

* www.calmarlaser.com

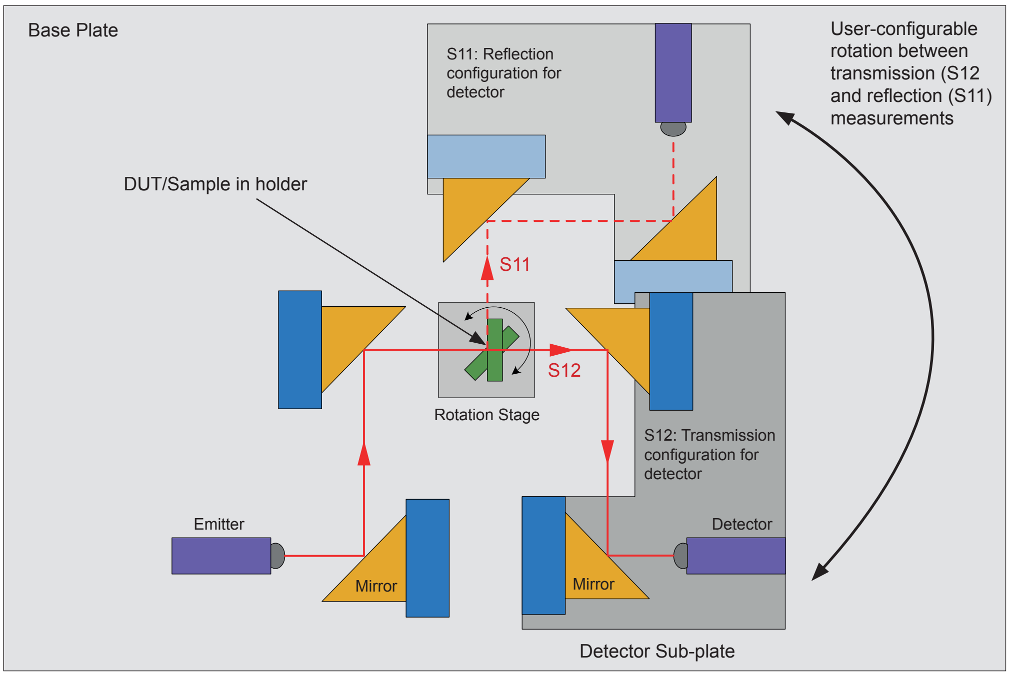

Figure 5
User configurable module for S12 and S11 free space measurements

The 6GSolve system is comprised of:

- A core TeraPulse unit that is lightweight and portable, and is available in desk-top format (433 x 450 x 222 mm).
- Remote heads (emitter & receiver, placed up to 2.8 m from core unit) for configurable transmission (e.g. S_{12}) or reflection (e.g. S_{11}) measurements.
- A free-space s-parameter module that allows for manipulation of emitter and detector beam paths for transmission and reflection measurements.
- Software package optimised to return accurate information on complex dielectric and conductivity.
- Optional heated cell for high T (up to 120^0 C) for accelerated lifetime test.

Performance specifications

Measurements:	Coherent measurement of amplitude and phase
Spectral range:	~ 40 GHz - 3 THz, with down to 30 GHz targeted
Peak dynamic range:	> 95 dB
Spectral resolution:	Better than 5 GHz, user selectable, with 1 GHz targeted
Measurement time:	Typically < 10 seconds
Quantities measured:	Complex conductivity, complex dielectric and loss tangent, absorption and refractive index

Customer case study – Teflon®

A TeraView customer wanted to characterize the frequency response of a new type of fluoropolymer, related to Teflon®. Teflon is a key material for 6G because it used extensively in computer cables, smart devices, wearables and in printed circuit boards. Its superior dielectric properties and low dissipation factors provide ultra-high frequency and high-speed performance. The customer stated that they 'needed a dielectric test system to characterize their Teflon material to 1 THz, to test their material at a given frequency and its first and second harmonics'. The conventional VNA system was seen by the customer as 'cumbersome to use and requires us to change the test fixture for each frequency range. We would rather have equipment that handles broad range of frequency with no change in fixtures'.

The customer approached TeraView because they were aware that a terahertz time domain systems (TDS) was a possible solution to provide continuous coverage without the need for change of test fixtures. Results are shown which plot the dielectric constant, ε', against frequency for transmission through Teflon samples using both third party VNA and TeraView solutions. Because of the limited (banded) frequency coverage of the VNA system, coupled with the added need in this case for the use of waveguide structures to couple into the Teflon which further reduces the frequencies available, the VNA data (see individual points on the graph) is extremely limited. By contrast, TeraView's technology suffers no such limitations, and is able to show data continuously between ~ 30 GHz - 3 THz and beyond. Moreover, the ease of implementing test fixtures meant this approach could be used to study a wide range of parameters affecting material performance, including temperature; in the example below, temperature dependence of the Teflon dielectric constant, ε', is shown, whereas this was not possible with the VNA-based system.

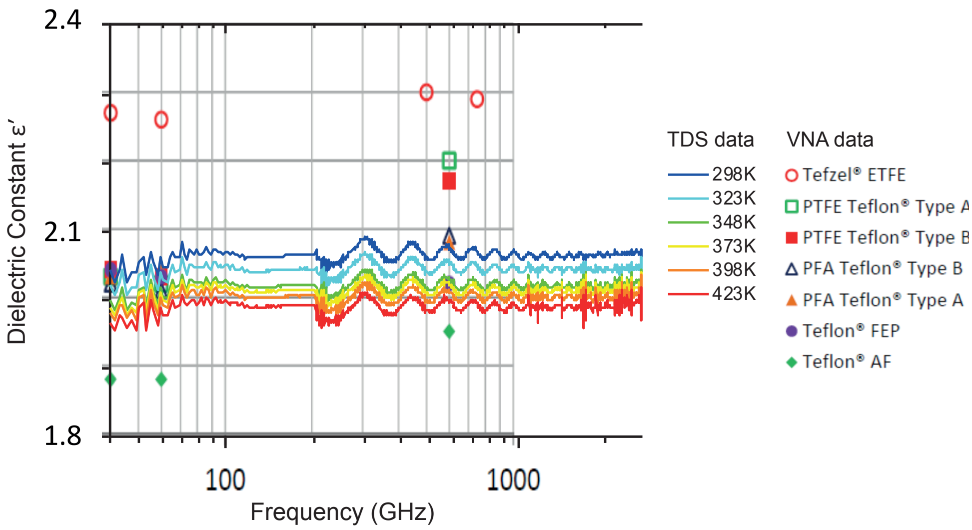

Figure 6
Dielectric constant ε'
(inc. data from Du Pont 2015)