Application Note

Anritsu envision : ensure

Measuring Path Loss of 5G FR2 Transmissions Through Common Materials Found in the Signal Path

Introduction

2019 saw the launch of the first commercial 5G networks in countries around the world. The promise of 5G networks is to improve the consumer and industrial user experience as well as deliver services never before possible over cellular networks (e.g., massive Internet of Things [IoT] and support for autonomous vehicles). Previous generation LTE networks typically deployed radio technology below 3 GHz. At those frequencies, propagation loss was not so severe as to prevent macro base stations from providing wide area coverage over many kilometers. However, the densification of LTE networks saw the use of many rooftop installations in urban areas. Many building landlords required “sight screens” to be installed so that the antennas and transmission equipment were not visible from street level. The careful choice of materials meant that these sight screens caused minimal signal loss in normal operation.

The first generation of 5G networks are being rolled out in the 3.5 GHz band (3GPP call sub-6 GHz implementations FR1) as well as the 28 and 39 GHz bands (which 3GPP call FR2). In the FR2 bands, the distance between base stations or small cells needs to be very short to provide reliable wide area coverage. FR2 radios have an effective coverage radius of a few hundred meters. 5G radio deployments will continue to be on rooftop sites and will now also include street lampposts or dedicated poles. 5G FR2 radios in some American urban centers are being deployed every 100 meters. Unlike with LTE deployments, the materials used for the sight screens on rooftops and antenna covers on street poles can have a significant effect on the signal loss from a 5G radio. This can force the radio to transmit less efficiently at a higher power or reduce the coverage from each radio.

Therefore, careful selection of the materials used for the rooftop sight screen or street pole radome of a 5G deployment is essential to ensure optimum network performance. Materials should be accurately measured and characterized for their RF attenuation properties. This application note highlights how to perform quantitative measurements of the attenuation of a range of material in the FR2 frequency bands utilizing the Anritsu Microwave Site Master™ S820E handheld cable and antenna analyzer. It also highlights the additional losses that can result directly from rainfall and the absorption of water by certain materials that may be selected for screens.

Above figure shows a typical 5G FR2 radio rooftop installation. The radio is just visible through the cut out in the sight screen that has been erected to hide the radios from street level.

Above figure shows an installation crew placing a cosmetic panel in front of the radio that has been tested to ensure low attenuation in all weather conditions.

Steps to Measure Insertion Loss of Various Materials

For this application note, the following items were used to measure path loss of 5G FR2 signals:

- Microwave Site Master S820E-0740 instrument with coverage to 40 GHz
- Two Ka band horn antennas (P/N 2000-1868-R)
- Two waveguide to coaxial converters (P/N 35WR28KF)
- Two test port coaxial cables (P/N 14RKFK50-0.6 or 14RKFK50-1.0)
- Two tripods & mounting hardware to secure the horn antenna(s) to the tripod(s)
- Optional if in a lab environment: Manual or automatic turntable which can be used to vary the angle of the material under test
- Various materials to test (for this application note, the following materials were tested: drywall, a wood panel, regular and low-E thermopane windows, fiberglass insulation, and an office cubicle partition made of metal and a material paneling)

Setup of the Microwave Site Master S820E Instrument for the Material Measurements

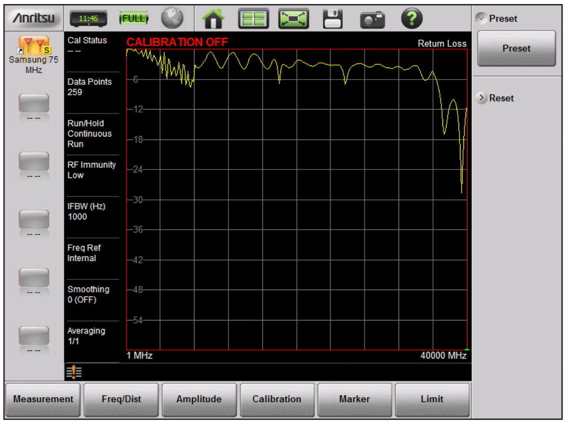
This section will provide a step-by-step walk thru of exactly how the Microwave Site Master S820E instrument was setup and calibrated before actual measurements took place. This step is important to ensuring a normalized 0 dB transmission response before inserting the various materials to test.

1. Ensure the Microwave Site Master S820E instrument is in the default Advanced Mode Cable Antenna Analyzer (Figure 1).

Select Advanced Mode

Figure 1. Main menu

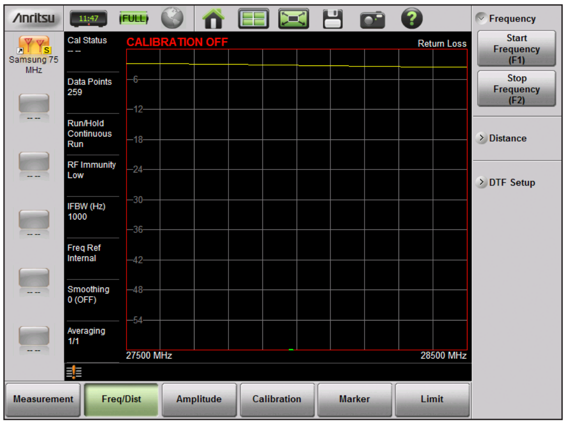
2. Preset the instrument to obtain a known state of operation (Figure 2).



Cal Status ---
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 0 (OFF)
Averaging 1/1

Figure 2. Preset

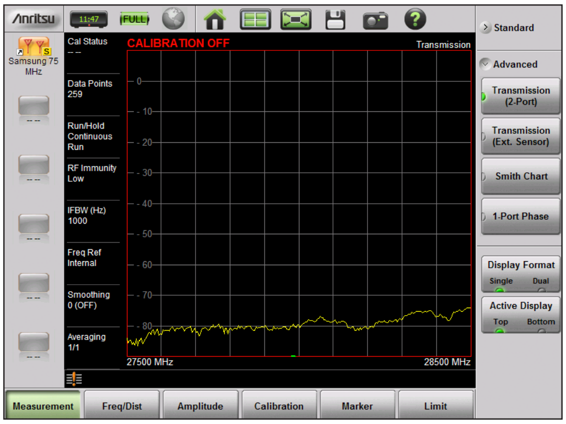
3. Set the Start & Stop frequencies to the range of interest. For this application note, the Microwave Site Master S820E was set to 27.5 GHz to 28.5 GHz (Figure 3). Your range may be adjusted to meet your specific requirements.



Cal Status ---
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 0 (OFF)
Averaging 1/1

Figure 3. Start/Stop frequency

4. Set the Measurement type to Transmission 2 Port, found under the Advanced Measurement selection (Figure 4).



Cal Status
-- --

Data Points
259

Run/Hold
Continuous
Run

RF Immunity
Low

IFBW (Hz)
1000

Freq Ref
Internal

Smoothing
0 (OFF)

Averaging
1/1

Figure 4. Transmission (2-Port)

5. Mount the horn antenna(s) to the tripod(s) securely (wire zip ties work well for this) and adjust them so that both antennas are at the same height. Aim the antennas directly towards each other and space them far enough apart to allow room for the materials to be placed in between. In this example, the antennas were placed 60 cm (~24”) apart. While this is a reasonable distance for smaller samples of materials, if a turntable is used to change the angle of the material then this distance should be increased so that the material does not come into contact with the antenna(s) or tripod(s). Distances up to 1 meter should be adequate for the majority of use cases when a turntable is being used (or larger material samples are being measured) and will not significantly impact the dynamic range or accuracy of the measurement. Connect the antenna(s) to the Microwave Site Master S820E test ports using cables and adapters as required. See Figure 5 for an example.

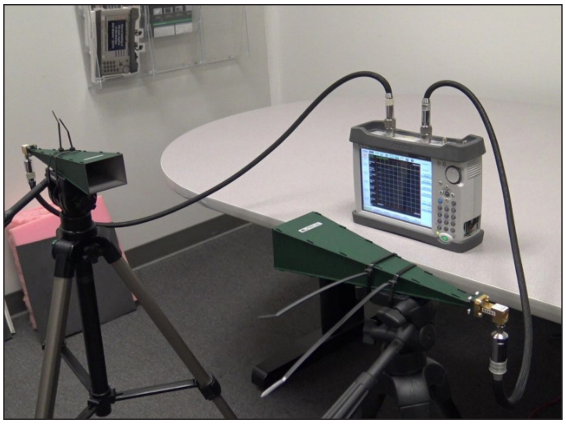
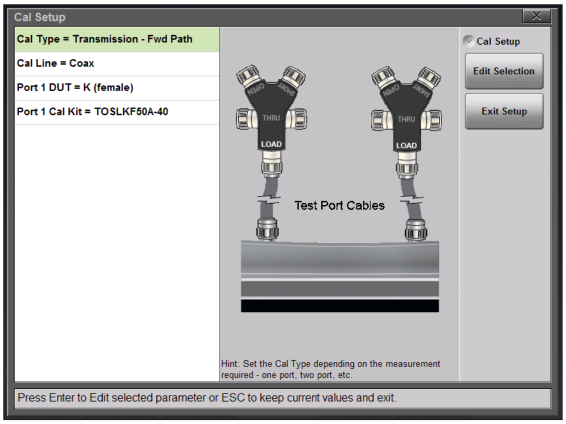


Figure 5. Example of connected setup

6. Once the antennas are properly aligned and stable, verify that the instrument is displaying a transmission measurement trace then go to the Calibration menu and set the Cal Type to TRFP: Transmission – Fwd Path (Figure 6). Since only a transmission calibration is being performed, no other cal components are needed and the calibration can begin. Skip Step 1 of 2 (Isolation) (Figure 7) that appears in the calibration menu, then press the Measure button to complete Step 2 of 2. When the “Thru” sweep from Step 2 is completed, press the Apply button to apply the calibration. The Microwave Site Master S820E instrument should now be sweeping with a normalized amplitude response trace positioned at 0 dB (Figure 8).

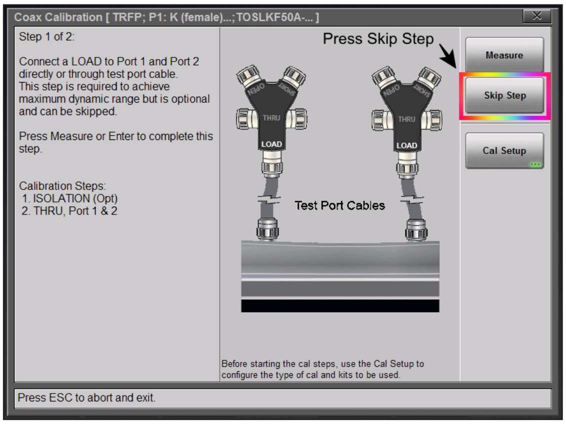


Cal Type = Transmission - Fwd Path
Cal Line = Coax
Port 1 DUT = K (female)
Port 1 Cal Kit = TOSLKF50A-40

Hint: Set the Cal Type depending on the measurement required - one port, two port, etc.

Press Enter to Edit selected parameter or ESC to keep current values and exit.

Figure 6. Cal Type



Step 1 of 2:

Connect a LOAD to Port 1 and Port 2 directly or through test port cable. This step is required to achieve maximum dynamic range but is optional and can be skipped.

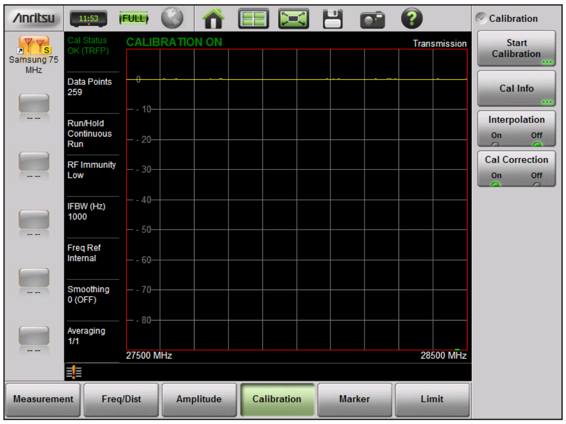
Press Measure or Enter to complete this step.

Calibration Steps:
1. ISOLATION (Opt)
2. THRU, Port 1 & 2

Before starting the cal steps, use the Cal Setup to configure the type of cal and kits to be used.

Press ESC to abort and exit.

Figure 7. Skip Step



Cal Status
OK (TRFP)

Data Points
259

Run/Hold
Continuous Run

RF Immunity
Low

IFBW (Hz)
1000

Freq Ref
Internal

Smoothing
0 (OFF)

Averaging
1/1

Figure 8. Normalized Transmission response

7. You are now ready to insert the various materials to be tested. Note: If an antenna(s) or tripod(s) is moved by accident or the normalized response is no longer at 0 dB, re-align the antennas and simply perform a Thru Update (this button will now appear in the Calibration menu) to restore a perfectly normalized 0 dB response.

Measurement Results of Various Building Materials

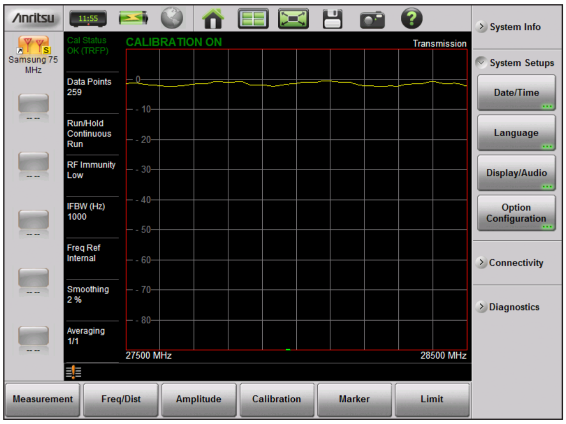
As noted earlier, for this application note a variety of materials commonly found in office buildings were tested (drywall, a wood panel, regular and low-E thermopane, fiberglass, and an office cubicle partition). One can see from the results in Table 1, these materials can be the cause of dramatic loss to a 5G signal. Let’s look at each measurement in a bit more detail.

Material Tested	Drywall A.K.A. Gypsum or Sheetrock	Wood panel 18 mm (3/4”)	Regular thermopane window	Low E thermopane window	Fiberglass insulation 200 mm (8”)	Office cubicle partition
Average loss	~ 3 dB	~ 4 dB	~ 3 dB	~ 43 dB	< 0.5 dB	> 60 dB

Table 1. Results of various building materials tested. Frequency range from 27.5 GHz to 28.5 GHz.

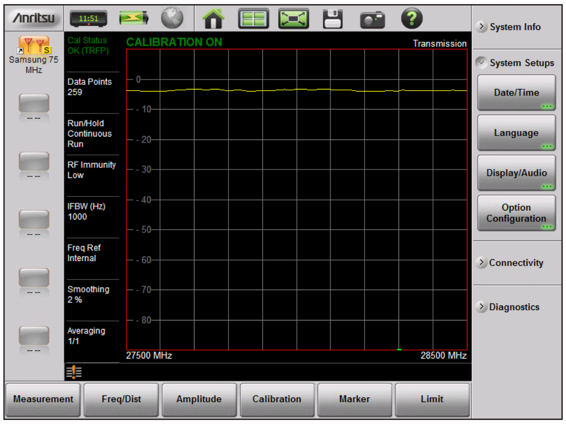
Drywall and Wood Panel

The measurement results, shown in Figures 9 and 10, show that these two common building materials should pose no significant issues in regards to signal loss and that FR2 signals are able to propagate well through these materials.



Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 9. Drywall or Gypsum

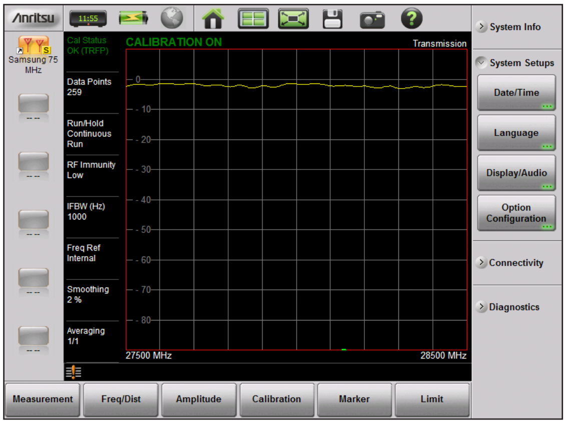


Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 10. Wood Panel

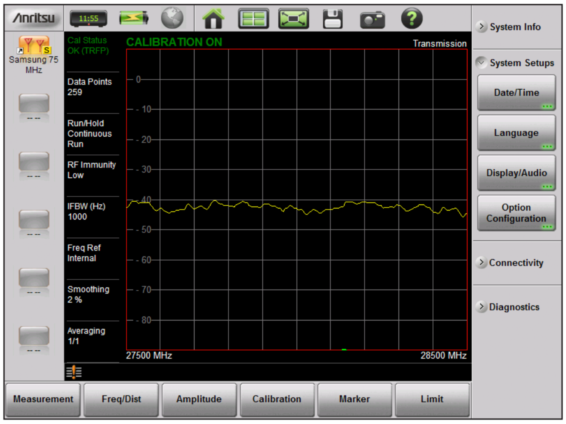
Thermopane

Figures 11 and 12 are a comparison of 2 types of thermopane windows commonly used in most buildings – regular and low-E. The results show that while FR2 signals are able to propagate (penetrate) through the regular thermopane window (Figure 11) easily with little loss, the low-E thermopane window (Figure 12) becomes a barrier for the FR2 signals. Because of the low-E window's special reflective coating, the FR2 signals are not able to propagate through these types of windows. This will present some significant challenges since many newer buildings (residential or business) utilize low-E thermopane windows for their excellent overall energy efficiency. With significantly lower penetration of FR2 signal levels inside the building from 5G gNB external base stations, users could experience dropped calls, an inability to connect to a network, and very slow data speeds. All of the desired benefits provided by the wide bandwidth available in the FR2 bands will be negated by the high losses caused by the low-E type windows.



Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 11. Regular thermopane window

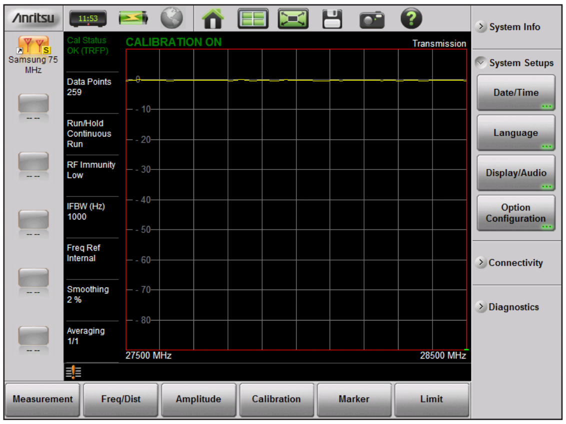


Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 12. Low E thermopane window

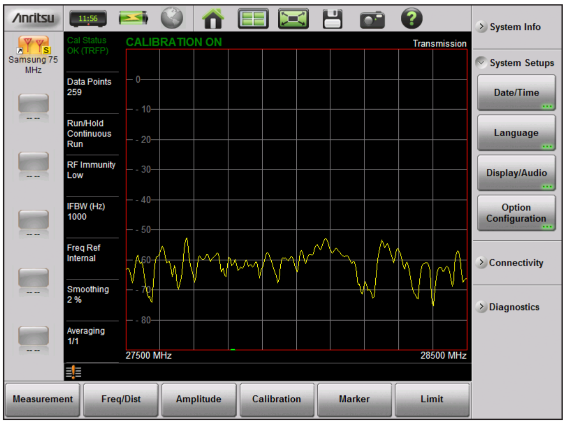
Fiberglass and Office Cubical Partition

Figure 13 shows that commonly used fiberglass insulation certainly poses no threat for FR2 signals. In contrast, the result of the office wall cubicle material (Figure 14) is absolutely catastrophic to the FR2 signals. This particular office cubical material would pose significant problems for indoor FR2 signal coverage. Manufacturers of office cubicle materials should investigate using different materials to obtain the desired structural strength of the cubicle partitions while ensuring FR2 propagation loss is minimized. Alternative materials will need to be considered with a focus on ensuring minimal propagation losses at FR2 frequency bands. Currently there are numerous new materials being developed and characterized for these applications, so we can expect to see new products being introduced with specific focus on minimal FR2 band signal losses.



Cal Status OK (TRFP)
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1

Figure 13. Fiberglass insulation



Cal Status OK (TRFP)
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1

Figure 14. Office cubicle partition

Effects of Moisture and/or Rainfall

What are the effects of moisture and/or water when it is present in the path between the transmitter (5G base station) and receiver (5G mobile) or when moisture is absorbed by certain materials? From the results shown in Table 2, we can see that when dry materials absorb moisture or water is present in the path the insertion loss increases significantly.

Material Tested	Simulated heavy rainfall*	Water sheeting on glass	Dry Canvas 4 layers thick	Wet canvas 1 layer thick**	Dry open cell foam 25 mm (1”)	Wet open cell foam 25 mm (1“)
Average loss	~ 3 dB	~ 17 dB	< 0.5 dB	~ 10 dB	0 dB	~ 18 dB

Table 2. Effects of moisture and/or rainfall. Frequency range from 27.5 GHz to 28.5 GHz.

**Actual loss caused by heavy rainfall increases with distance. Measurement example distance was only ~ 15 cm (6”). See Figures 15a and 15b below.*

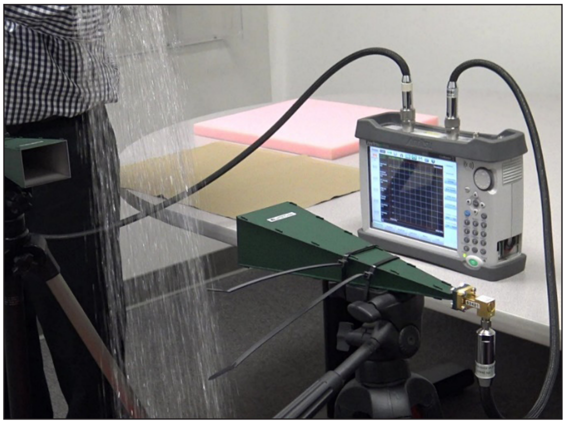
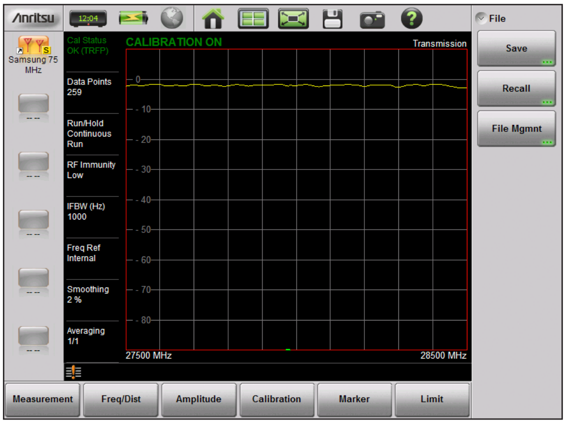


Figure 15a. ~15 cm (6”) of simulated heavy rainfall



Cal Status OK (TRFP)
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1

Figure 15b. Simulated heavy rainfall results

The regular thermopane window's loss was ~3 dB (Table 1), however that same window's loss with water sheeting on it increased significantly to ~17 dB (Table 2). This could easily occur when a strong rainstorm with high winds forces the rain to fall angularly onto the glass (Figures 16a and 16b).

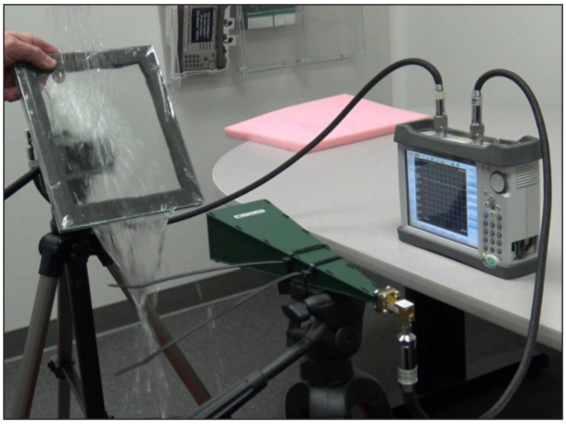
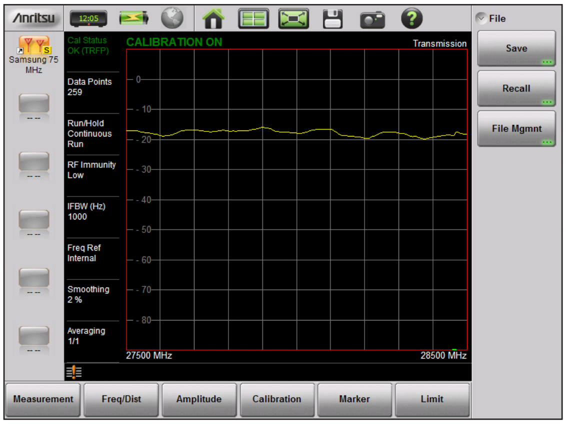


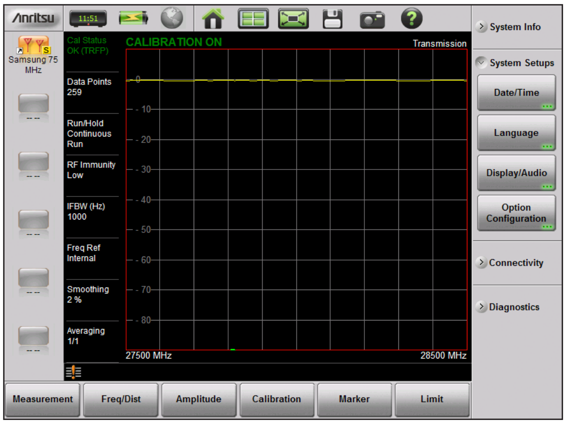
Figure 16a. Water sheeting on Thermopane



Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

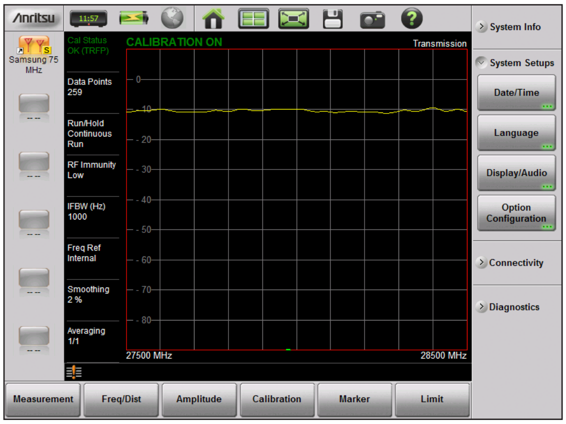
Figure 16b. Water sheeting on Thermopane results

Looking at the dry canvas measurement results (<0.5 dB) in Table 2, a person may conclude that canvas fabric would be a good choice for concealing antennas and/or 5G base stations since it is easy to work with, durable, and very flexible. However, if not properly treated to prevent moisture absorption, the canvas material would become one of the worst possible choices as its loss increases significantly once it has absorbed any amount of moisture. One layer of wet canvas had ~10 dB of loss (Figures 17a and 17b).



Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 17a. 1 layer of dry canvas material

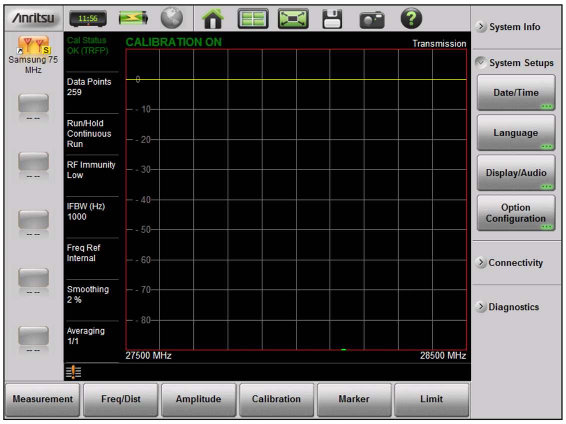


Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 17b. 1 layer of wet canvas material

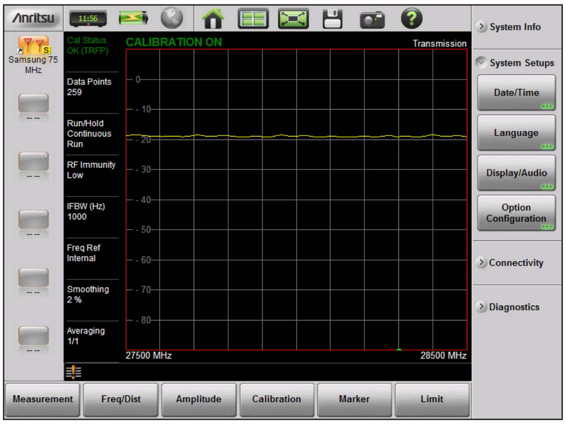
*** Each additional layer of wet canvas added another 10 dB of loss (approximately). 4 layers of wet canvas has an accumulated ~40 dB* of loss.

For example, if an antenna system was concealed using very thick and rugged canvas, which was equivalent to 4 layers of the sample used, the insertion loss is <0.5 dB when dry, however, after the canvas has absorbed moisture the insertion loss increased to ~40 dB. In this example the loss of the wet canvas is so great that most likely the connection would be lost. (Note: You can see this effect (and others) directly in real time on 4 layers of canvas in the video available at www.anritsu.com). Dry vs. wet open cell foam exhibited similar characteristics compared with the dry vs wet canvas (Figures 18a and 18b).



Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 18a. Dry open cell foam



Cal Status OK (TRFP)
CALIBRATION ON
Transmission
Data Points 259
Run/Hold Continuous Run
RF Immunity Low
IFBW (Hz) 1000
Freq Ref Internal
Smoothing 2 %
Averaging 1/1
27500 MHz
28500 MHz

Figure 18b. Wet open cell foam

Summary

The large scale deployment of FR2 5G radios on rooftops in urban areas is certain to lead to demands by building landlords to provide sight screens to prevent radios being seen from the street. 5G signals must also penetrate indoors to provide universal network coverage. These requirements mean that the signal path loss through a wide range of materials used in the construction and cladding of buildings must be understood. The Anritsu Microwave Site Master S820E handheld cable and antenna analyzer, when used with the waveguide horn antenna(s), can quickly be configured and calibrated to provide quantitative insertion loss measurements of a wide range of materials. With this information, network planners can model network coverage and select materials that provide the best compromise between durability and aesthetics without compromising network coverage and user experience.

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Specifications are subject to change without notice.

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