

# Transmission Measurement Options

## with Site Master MS2085A and MS2089A

### Introduction

One of the most common measurements made on RF components is transmission loss or insertion loss. This measurement defines the basic characteristics of components such as cables, filters, and amplifiers. The measurement concept is simple: an RF signal source input to the device under test (DUT) sweeps the frequency span of interest, and a detector or receiver measures the output from the DUT. In this way, the insertion loss or gain and the frequency response are plotted on the instrument display.

The Anritsu Site Master MS2085A and MS2089A instruments are designed to be used in the field, where the measurement of cable loss at transmitter towers is essential. A site may also require insertion loss and frequency response testing of additional components, including filters, duplexers, and amplifiers. This application note analyzes the different techniques used for these measurements and their relative strengths and limitations.

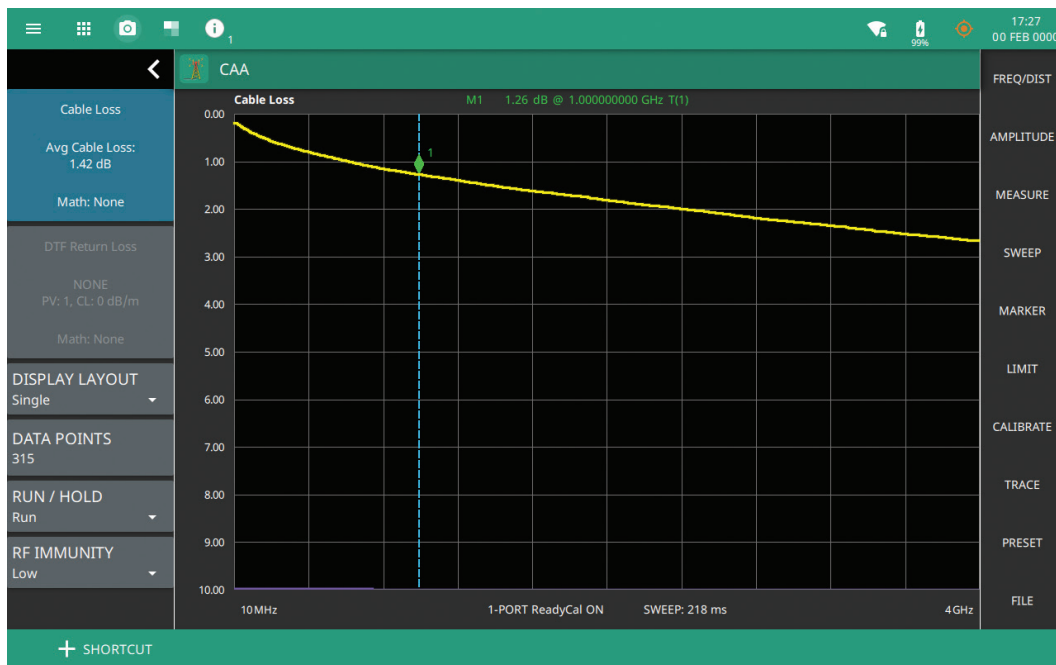
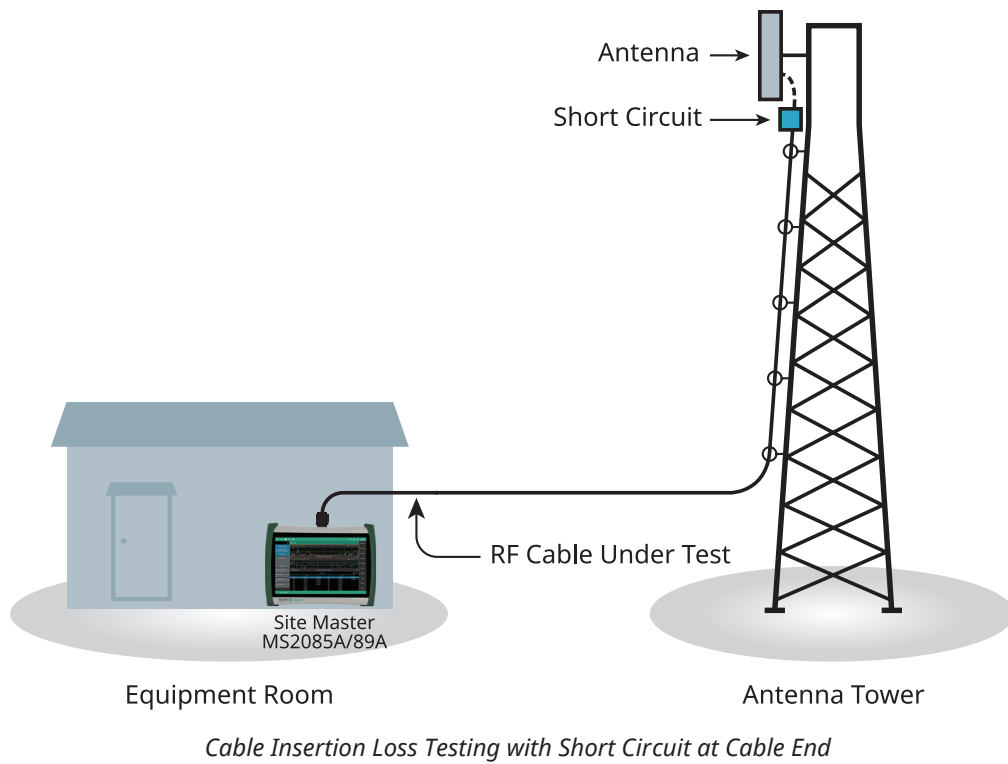
### Basic Cable Insertion Loss Techniques

There are a number of techniques that can be used for cable insertion-loss measurements. The most basic method uses only one instrument measurement port. By connecting a short or an open to the far end of the cable (in some cases simply leaving the cable unterminated is acceptable), the open or short circuit reflects 100% of the power injected into the cable. The signal experiences loss in both directions—towards the end of the cable and again as it returns—before the reflected signal is measured at the input port. By dividing the total loss by two (because the signal travels through the cable twice), the insertion loss is calculated and displayed.

This is the simplest form of cable insertion loss measurement because it does not require accessing the far end of the cable to connect to a second instrument port. In the case of long cables or cables permanently mounted on a tower, accessing the far end may not be possible. This technique is the most common method for testing long cables in the field; however, it does have some dynamic range limitations and works best when cable loss is less than 15 dB—ideally less than 10 dB.

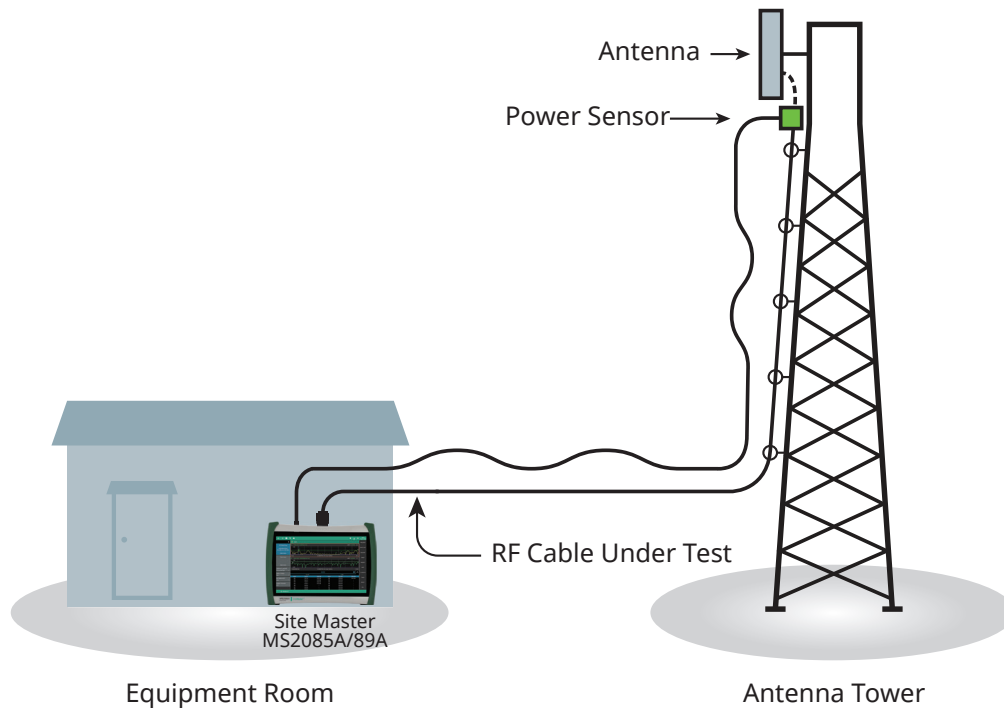
#### Example:

Incident signal level at Port 1 is 0 dBm and is injected into the DUT cable. The forward path loss is 2 dB, so the signal level at the end of the cable is -2 dBm. The -2 dBm signal is fully reflected and attenuated by another 2 dB on the reverse path, so the signal returning to Port 1 is -4 dBm. Because the signal traveled twice through the cable, the cable loss is half the total round trip loss, resulting in a final value of 2 dB.



*Cable Insertion Loss Measurement with Short Circuit Termination Showing 1.26 dB Loss at 1 GHz*

A refinement of this technique is to connect a power sensor to the far end of the cable and measure the output power relative to the input power. This can provide a more accurate result, but it is slower to sweep and requires physical access to the far end of the cable.



*Cable Insertion Loss Testing with Power Sensor at Cable End*

Both of the above methods provide limited dynamic range because the 1-port reflection technique divides the total loss by two, and power sensors are broadband with limited dynamic range. The 1-port technique works well up to approximately 10–15 dB of loss, while the power sensor technique is suitable up to 40–50 dB (depending on the sensor).

For applications requiring a wider dynamic range, a 2-port receiver based measurement is typically used. This requires the cable to be accessible at both ends and is often performed before the cable is installed permanently.

## Receiver Base Insertion Loss Measurement Techniques

The Site Master instruments offer three receiver-based methods to make this measurement depending on the options installed.

1. Cable and Antenna Analyzer with Option 21 (2-port transmission measurements)
2. Vector Network Analyzer (2-port  $S_{21}$  measurement)
3. Spectrum Analyzer with Tracking Generator option

Methods 1 and 2 are provided using the Site Master MS2085A with the 2-port measurement option or full VNA option. Method 3 requires a spectrum analyzer and is available on the Site Master MS2089A with tracking generator option (or the standard Field Master MS2080A spectrum analyzer with tracking generator option).

The following examples highlight the strengths and limitations of each of these insertion loss measurements when characterizing a bandpass filter with approximately 100 dB out of band rejection. The filter is nominally centered on 1.9 GHz with 60 MHz bandwidth.

## Cable and Antenna Analyzer with Option 21 (2-port transmission measurements)

This measurement is available using a Site Master MS2085A or MS2089A with Option 21 in cable and antenna analyzer mode.

Put the instrument into CAA mode.

1. Select: FREQ/DIST

- Start frequency = 10 MHz
- Stop Frequency = 4 GHz

2. Select: MEASURE

- Count = 1
- Measurement = Transmission (Port 2)
- Display layout = Single

3. Select: SWEEP

- Data points = 1001
- Output power = High

4. Select: CALIBRATION

- Method = Trans(Port 2)
- Mode = Flex
- Start Cal

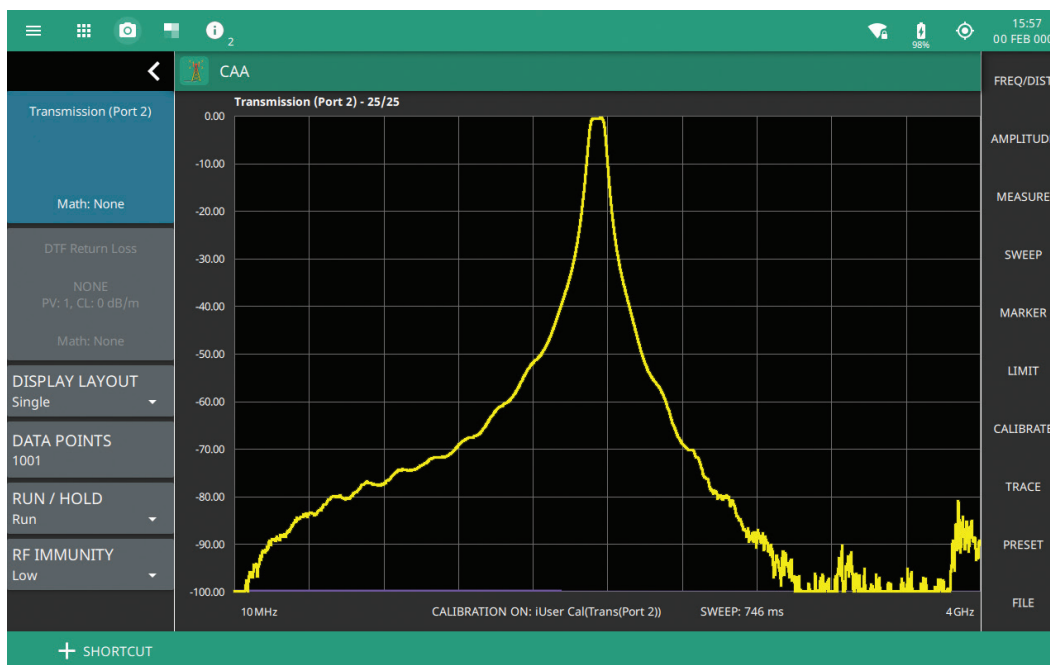
*(Then follow the calibration wizard prompts to complete the calibration)*

On completing the calibration with the cable used for calibration still connected, the trace will form a flat line at 0 dB across the screen. To maximize the on-screen dynamic range while maintaining a convenient amplitude scale:

5. Select: AMPLITUDE

- Top = 0 dB
- Bottom = -100 dB

Inserting the bandpass filter results in the following measurement of the filter passband and rejection. Sweep averaging has been set to 25 sweeps to smooth the noise at low power levels.



*The Above Screen Image Highlights that even in CAA Mode, 100 dB of out of Band Rejection can be Measured*

## Vector Network Analyzer

This measurement is available using a Site Master MS2085A or MS2089A with the Vector Network Analyzer option.

Put the instrument into VNA mode.

1. Select: FREQUENCY
  - Start frequency = 10 MHz
  - Stop Frequency = 4 GHz
2. Select: POWER
  - Port 1 power = 10 dB *(set highest available levelled power to maximize dynamic range)*
3. Select: MEASURE
  - Count = 1
  - Graph type = Log Mag
  - Domain = Frequency
  - S Param =  $S_{21}$
  - Display layout = Single
4. Select: SWEEP
  - Data points = 1001
5. Select: CALIBRATION
  - Type = Trans(Port 2)
  - Mode = Flex
  - Start Cal

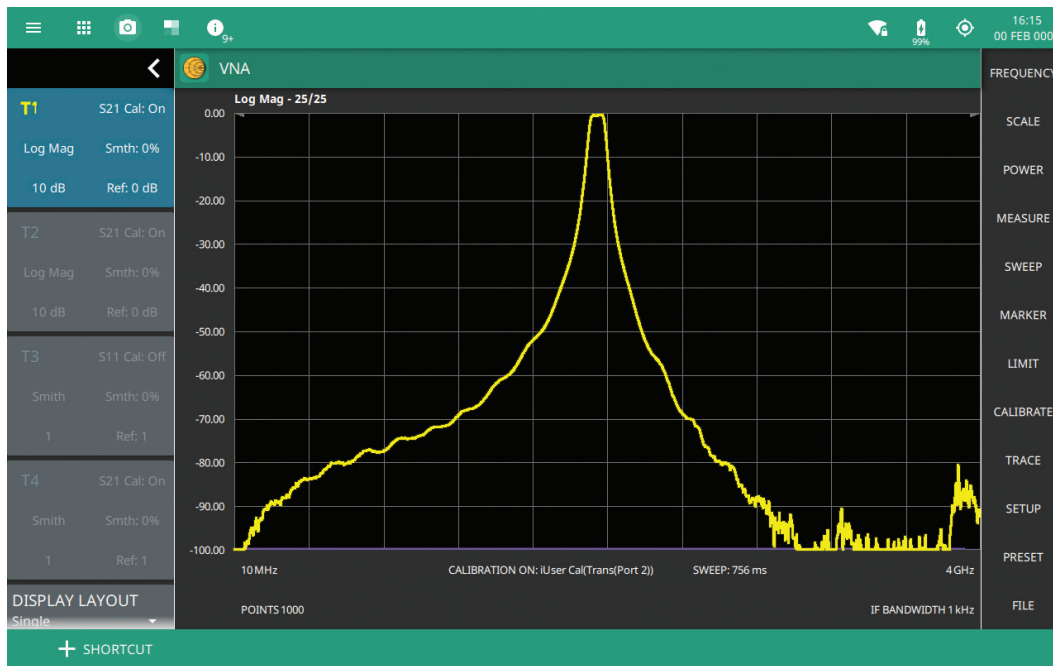
*(Then follow the calibration wizard prompts to complete the calibration)*

On completing the calibration with the cable used for calibration still connected, the trace will form a flat line at 0 dB across the screen. To maximize the on-screen dynamic range whilst maintaining a convenient amplitude scale;

#### 6. Select: SCALE

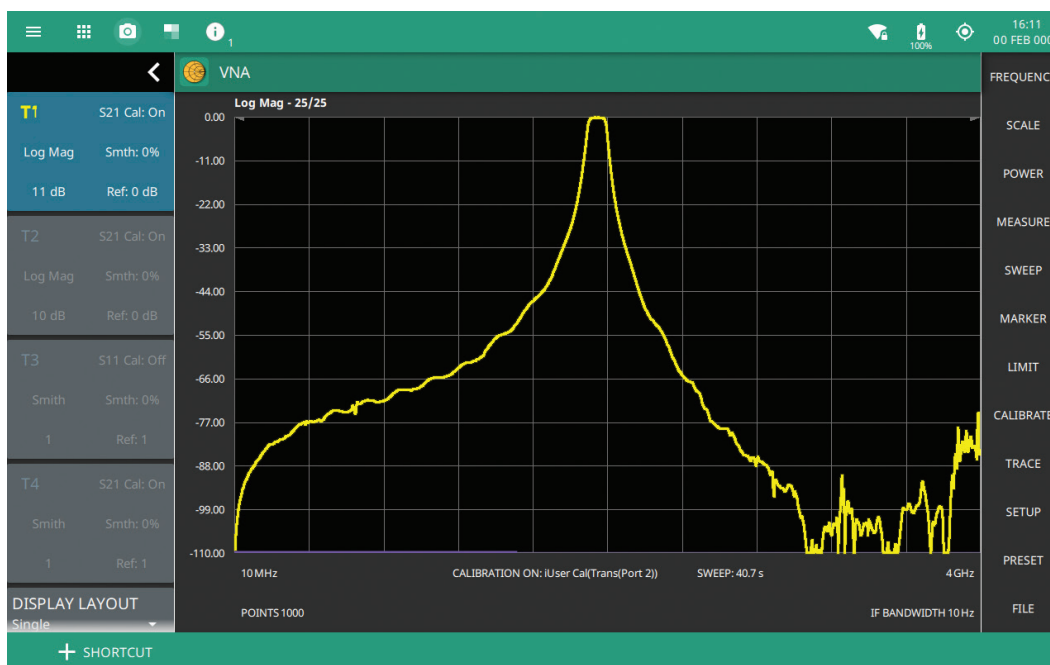
- Ref level = 0 dB
- Resolution = 10 dB
- Ref line = 10

Inserting the bandpass filter results in the following measurement of the filter passband and rejection. Sweep averaging has been set to 25 sweeps to smooth the noise at low power levels.



*The Above Screen Image Highlights that in VNA Mode, There is a Slight Improvement in Measurable Dynamic Range. This is Due to the Ability to Set a Higher Test Port Signal Power*

The VNA adds additional measurement flexibility to further increase dynamic range. By reducing the IF bandwidth of the VNA port 2 receiver, the noise floor is reduced further. In the display below, the IF bandwidth has been set to 10 Hz and the amplitude scale changed to 11 dB per division. Out of band filter rejection of up to 110 dB is now measured.

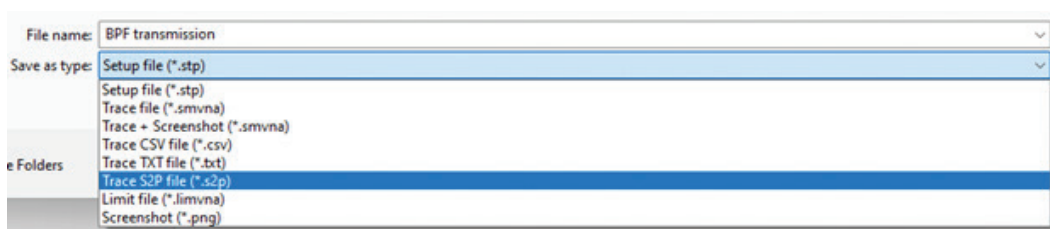


*Reducing the VNA IF Bandwidth to 10 Hz Increases the Dynamic Range Highlighted by Extending the Scale to 110 dB*

The VNA mode has additional benefits over the cable and antenna analyzer mode for the more experienced user. As well as user control over the receiver IF bandwidth, additional measurements are available including transmitted Phase, Unwrapped Phase, and Group Delay.



*This Screen Shows the Group Delay of the Bandpass Filter with a Typical Characteristic Group Delay Shape*



*In VNA Mode, the Trace Data can be Saved Using Common File Formats that Enable them to be Opened in Common Post Processing Software Such as Touchstone, ADS, and AWR*

## Spectrum Analyzer with Tracking Generator

This measurement is available using a Field Master MS2080A or Site Master MS2089A in spectrum analyzer mode.

Put the instrument into SPA mode.

1. Select: FREQ/SPAN

- Start frequency = 10 MHz
- Stop Frequency = 4 GHz

2. Select: MEASURE > GENERATOR

- Output = On
- Level = 8 dBm (set highest available levelled power to maximize dynamic range)

3. Select: SWEEP

- Data points = 1001

A spectrum analyzer in default configuration will select a wide resolution bandwidth to maximize the sweep rate. The Site Master analyzer RBW defaults to 5 MHz for a 4 GHz span. To increase the displayed dynamic range the RBW must be manually set to a narrower bandwidth. To maximize the on-screen dynamic range while maintaining a convenient amplitude scale;

#### 4. Select: BANDWIDTH

- Auto RBW = Off
- Manually set RBW to 1 kHz

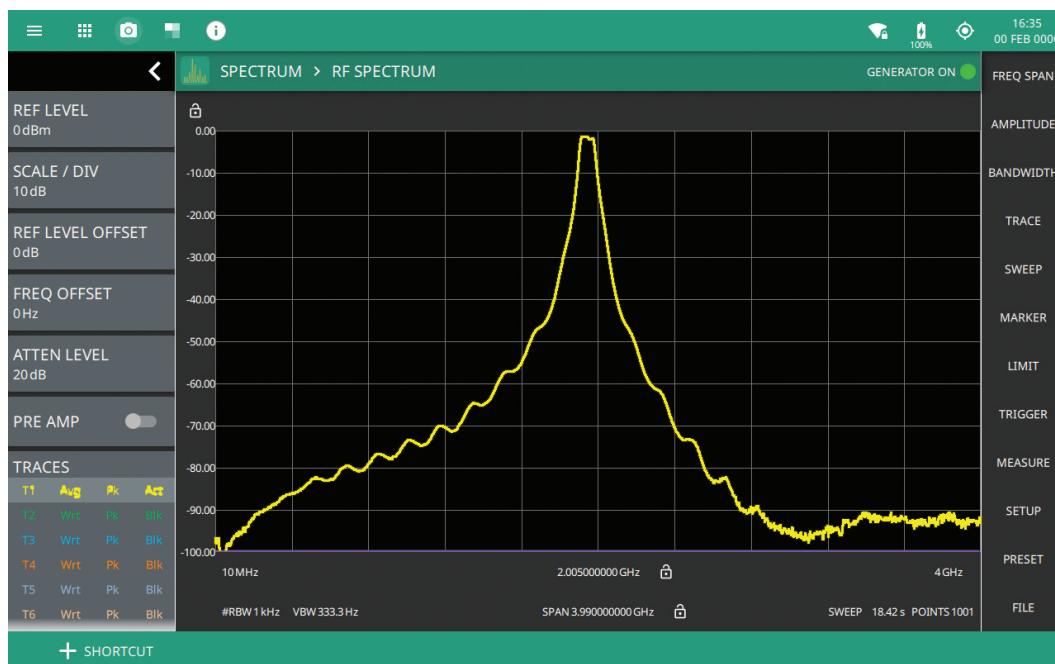
When using a spectrum analyzer with a tracking generator, the calibration for transmission measurements is commonly known as “Normalization”. To perform a normalization that provides a trace levelled to 0 dB correcting for the cable loss of the test port cables, connect a low loss RF cable between the tracking generator output and the spectrum analyzer input. Then follow the steps below in the Trace menu.

#### 5. Select: TRACE

- Normalize = toggle On

On completing the normalization with the cable used still connected, the trace will form a flat line at 0 dB across the screen. Note that the amplitude scale is now dB and not dBm. A second amplitude scale is shown on the right side of the graticule so that two live traces can be viewed on different amplitude scales.

Inserting the bandpass filter results in the following measurement of the filter passband and rejection. Sweep averaging has been set to 25 sweeps to smooth the noise at low power levels. Note that with the spectrum analyzer and tracking generator combination, the dynamic range of the measurement is not quite as good as for the VNA.



*This Screen Shows the Same Filter Measured with the CAA and VNA Measured with the Spectrum Analyzer and Tracking Generator*

Other limitations of the spectrum analyzer tracking generator combination is that a new normalization must be performed after any changes to the spectrum analyzer configuration such as a change to the RBW or amplitude scale. For this reason, many users of the tracking generator do not apply normalization and simply use the spectrum analyzer for a quick frequency response test of devices to validate basic performance

## Summary of Receiver-based Methods for Measurement of DUT Insertion Loss

|                       | CAA                         | VNA                                           | SPA + TG                                                                                                                |
|-----------------------|-----------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Dynamic Range         | Fair                        | Best                                          | Good                                                                                                                    |
| Sweep Speed           | Fast                        | Fast                                          | Slow (for high dynamic range measurements)                                                                              |
| Ease of Configuration | Simplest                    | Requires some understanding of VNA parameters | Simple for measurements without normalization. With normalization requires new calibration for any configuration change |
| Advanced Measurements | Basic log magnitude display | Yes: Phase, Unwrapped Phase, and Group Delay  | No                                                                                                                      |

The Anritsu Site Master MS2085A/MS2089A and Field Master MS2080A offer a range of techniques that measure cable or component insertion loss. This application note summarizes their best applications and relative strengths and limitations.



Specifications are subject to change without notice.

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