Application Note

# Ideal Pre-Emphasis Constant Setting

## MP1800A Series
Signal Quality Analyzer

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## 1. Introduction

Emphasis transmission technology is required when transmitting high-speed signals using backplanes and direct attach cables (DAC). As high-speed signals pass along the transmission path, loss is caused by the frequency characteristics of the transmission path and the transmission distance, causing reduced signal integrity. The number of transmission errors increase as the reduction in signal integrity increases and this is linked with drops in product quality. Drops in signal integrity can be suppressed by using low-loss materials at the backplane port and there are also methods for shortening the transmission path but these increase product costs and cannot need future needs for higher density and longer transmission distances. As a result, emphasis technology is being applied as a method for suppressing drops in signal integrity.

Emphasis technology prevents reduction in signal integrity by emphasizing high-frequency components of signals and can transmit signals over longer distances without errors. Since emphasis technology continuously varies the emphasis of the high-frequency components to match the DUT frequency characteristics, it can generate the optimum signal for transmission, but on the other hand, unnecessary excessive amplification can cause a drop in signal integrity. In addition, when transmission speeds increase from 10 Gbit/s to 25/28 Gbit/s, a 3 or 4 tap emphasis signal is required to increase the bits to be emphasized. Checking and setting the combination of emphasis rates for each tap is extremely complex and it is difficult to find the ideal emphasis signal without quantitative guidelines.

Anritsu has developed a method for finding the ideal emphasis signal that matches the transmission path characteristics using the MP1825B 4 Tap Emphasis (Fig. 1) and MX210002A Transmission Analysis Software (Fig. 2).

This Application Note explains the reduction in signal integrity caused by the transmission path, and proposes how to control reductions in signal integrity using emphasis technology and calculation of the ideal emphasis constant.

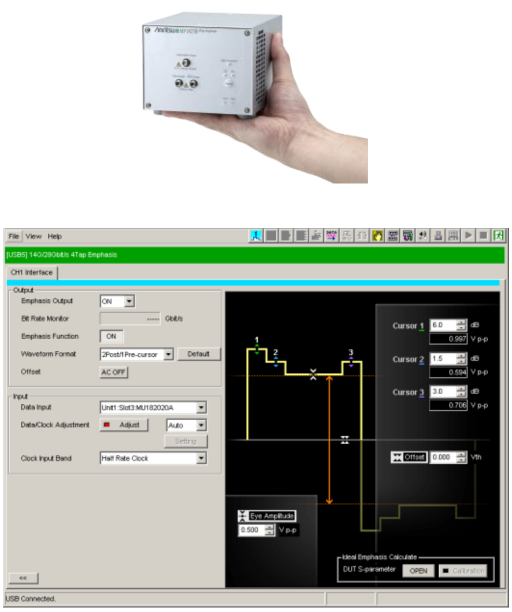


*Figure 1*

*MP1825B 4 Tap emphasis*

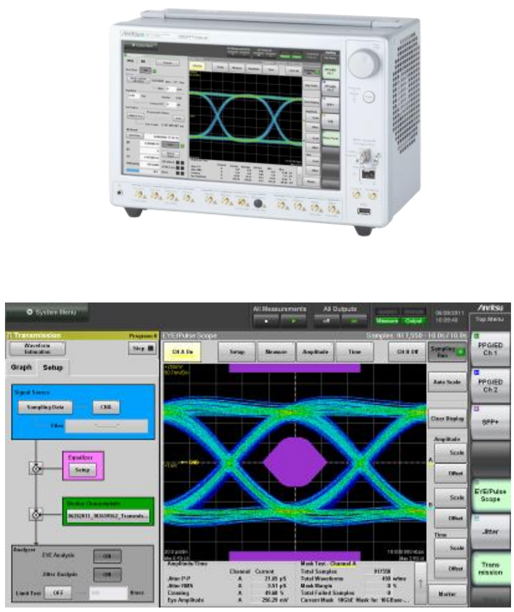


*Figure 2*

*MP2100A BERTWave*

*MX210002A Transmission Analysis Software*

## 2. Cause of Signal Integrity Reduction

One cause of reduced signal integrity is attenuation/loss and limited bandwidth. This section describes the features of transmission signals and the causes of reduced signal integrity that occur when the signal passes along the transmission path.

### Signal Format

The usual transmission signal format is NRZ but this format is a rectangular shape to maintain longer transmission times between 1 and 0 (Figure 3). An ideal rectangular waveform is formed by adding odd multiples of a sine wave at the data rate. (To be exact, it is formed by summing 1/N of the amplitude of N multiples of the harmonic.)

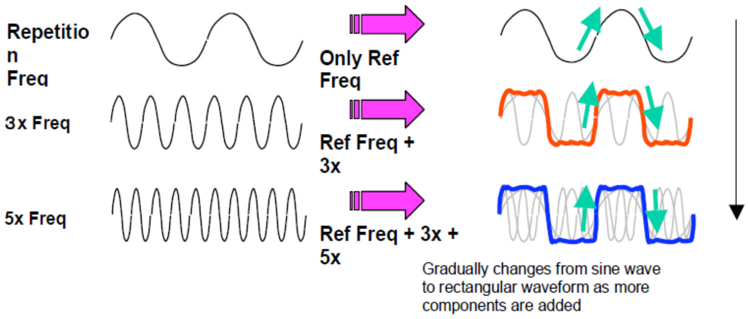



*Figure 3*

*Composition of pulse from sinusoidals*

When the N multiples of the frequency components are superimposed, the sine wave changes gradually to a rectangular waveform. The high-frequency components determine rise time, the point where 0 becomes 1 and 1 becomes 0. Lower frequencies make up the "flat top." The transition becomes sharper as more components are added. When viewed on a spectrum analyzer, the individual spectral lines described above can be seen clearly (Figure 4) as pulse spectrum (x-axis is frequency).

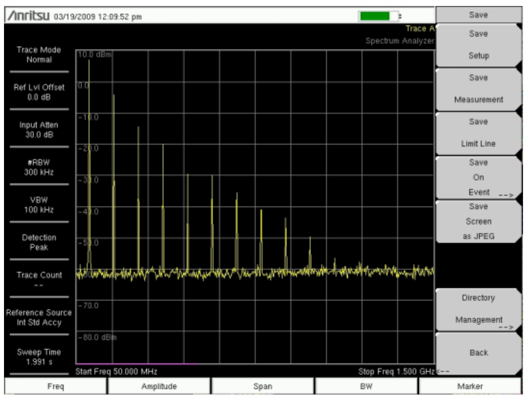


*Figure 4.*

*Spectral lines are spaced by the pulse repetition frequency;*

*the faster the rise time, the wider the occupied bandwidth.*

Attenuation/Loss

At the gigabit rates used today, PC board traces can have appreciable copper loss (I 2 R), skin effect (loss due to microwave part of signal traveling only on trace surface), as well as dielectric loss (absorption of energy by substrate material). These are all frequency-dependent losses. Loss can reduce the level to the point where a "1" is below the trigger point. Longer paths and higher frequencies lead to predictably greater losses. Figure 5 shows the frequency characteristics of a PC board. The x-axis is frequency and the y-axis is attenuation in dB.

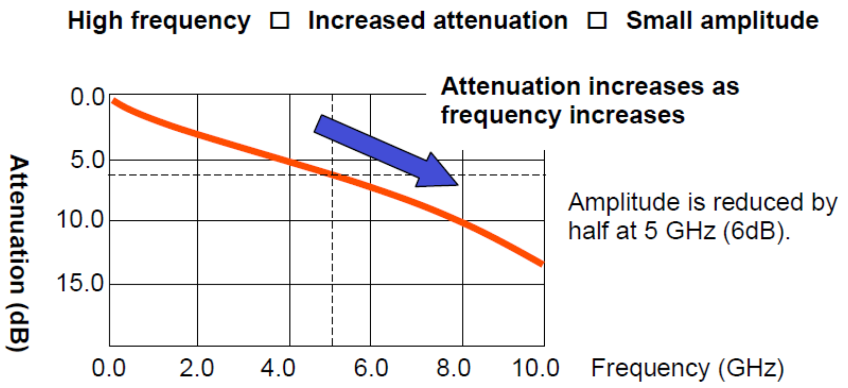



*Figure 5*

*PC board trace loss vs frequency*

**Limited Bandwidth**

As shown in Figure 6, a pulse applied with a fast 0 → 1 transition and a clean flat top can be highly degraded when it passes through a band-limited device or filter. This degradation manifests as ripple and slower 0 → 1 rise time. If the ripple has sufficient amplitude, high-speed circuit may interpret it as false transitions (Figures 6 and 7).

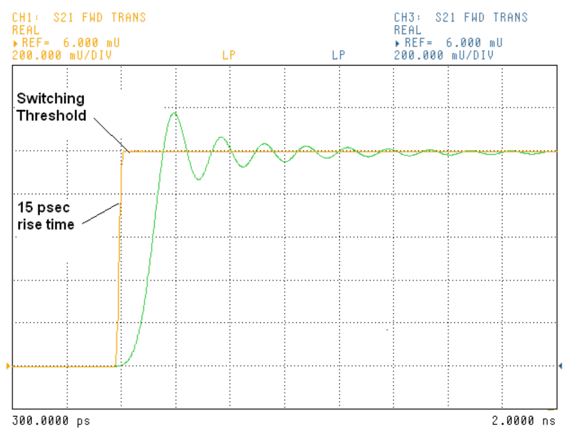



*Figure 6.*

*Ripple can cause false transitions*

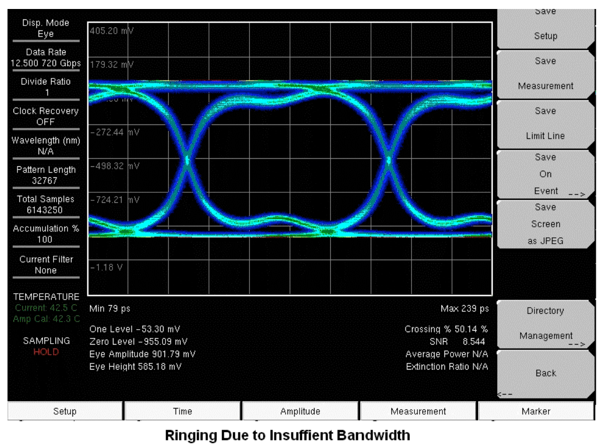



*Figure 7.*

*Ringing effect on eye pattern*

## 3. What is Emphasis Transmission?

Pre-emphasis and de-emphasis result in the same waveform shape. Pre-emphasis is commonly used in IC design, simulation, whereas de-emphasis is often used in test and validation vocabulary. De-emphasis considers the second bit in a series of 1s or a series of 0s to be attenuated, whereas pre-emphasis considers the first bit as sent with larger drive level. Boosting the amplitude of the first bit of a series of one or more identical bits has the effect of increasing the spectral energy at high frequency. This boosting helps to counteract the high-frequency loss of PC board traces. The result at the far-end is an Eye diagram with less distortion from the effects of Inter Symbol Interference (ISI). Figure 8 shows an example of a bit sequence for a 2 tap emphasis signal.

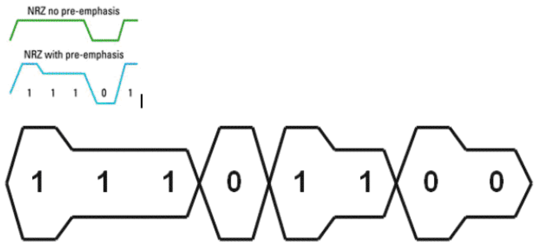



*Figure 8.*

*Effect of pre-emphasis on pulse leading edge*

The MP1825B 4 Tap Emphasis generates emphasis signals up to 4 taps with a maximum transmission speed of 28.1 Gbit/s. As shown in Figure 9, the configuration uses a serial input/parallel output type shift-register configuration and its output is summed. The 4-stage flip-flop circuit creates 4 tap emphasis. With this type of configuration, the amplitude of 1 bit before the shift bit, 2 bits after the shift bit (Figure 10) or 3 bits after the shift bit of the output signal 1 → 0 or 0 → 1 transition can be increased for each bit to either emphasize the high-frequency components or suppress the low-frequency components.

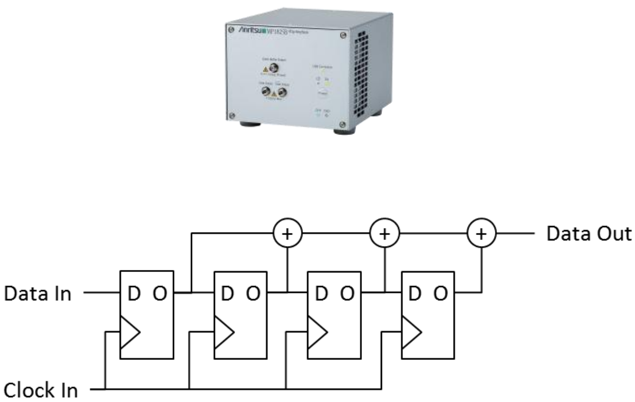



*Figure 9*

*MP1825B and block diagram*

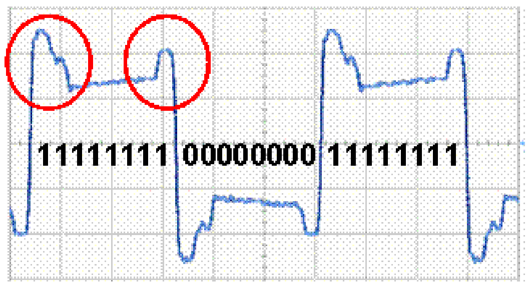
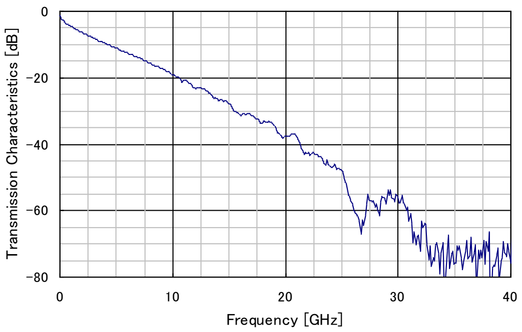



*Figure 10.*

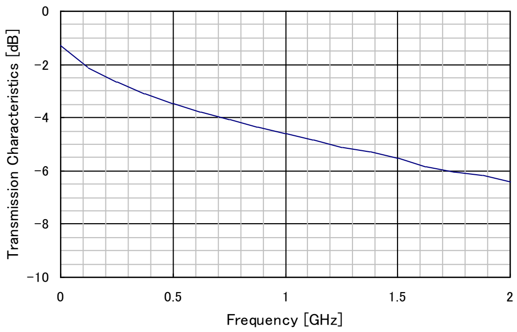
*Pre-emphasis waveform with 2Post/1Pre-cursor setting*

## 4. Emphasis Transmission Effect

Emphasis transmissions were used to evaluate the effect on frequency loss. A 27-inch backplane board with the frequency characteristics shown in Figures 11 and 12 were used to reproduce frequency loss. The transfer characteristics was about –2 dB/GHz near 25 GHz and the loss increased linearly. Additionally, the group delay was almost flat near 25 GHz.




*(a) Transmission characteristics up to 40 GHz*




*(b)Transmission characteristics <2 GHz*

*Figure 11*

*27-inch backplane board transmission characteristics*

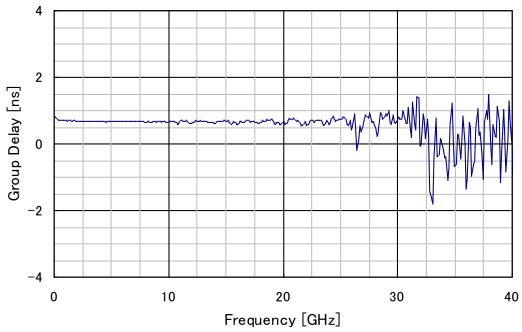



*Figure 12*

*Group delay of 27-inch backplane board*

Actual measurement compared the waveform before and after passing the 27-inch backplane board using the system shown in Figure 13.

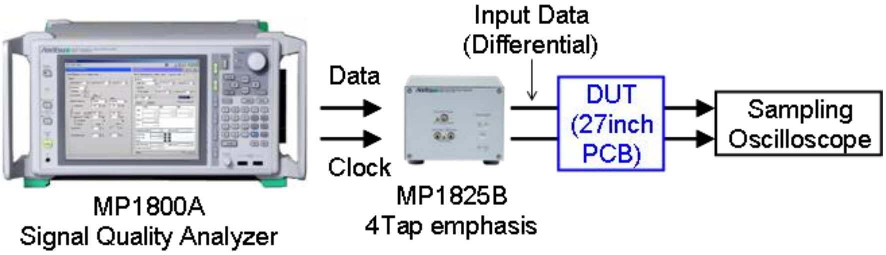
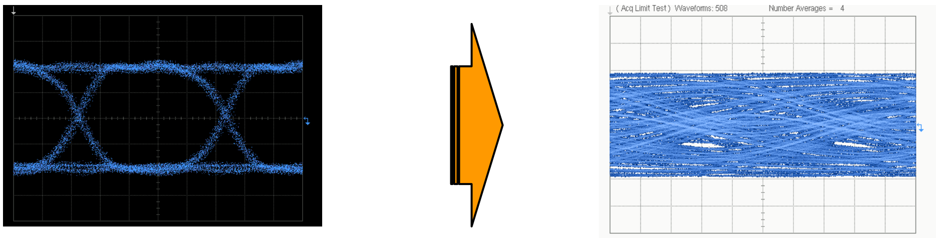



*Figure 13*

*Measurement system to confirm emphasis effect*

Figure 14 shows the waveform of a 20 Gbit/s pseudorandom pattern with emphasis off before and after passage through a 27-inch backplane. Based on Figure 11, the Eye Height after passage through the DUT is less than 1/9th of the input waveform, possibly because the DUT transfer characteristics is the 1/2 frequency of the Bit rate, or in other words, approximately –19.1 dB at 10 GHz. Consequently, since the Eye opening of the input waveform is about 720 mVp-p, the Eye opening after passage through the DUT is less than 80 mVp-p and the actual Eye opening is a closed waveform.

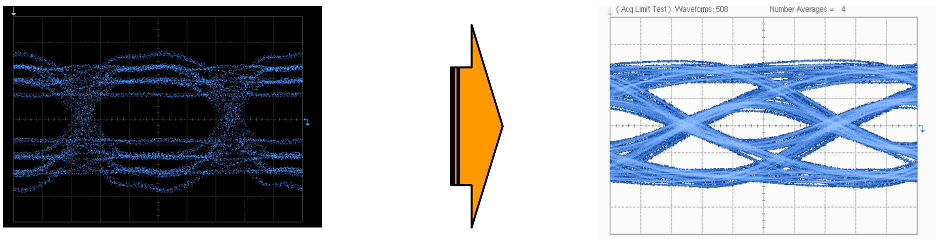


*(a) Input waveform (400 mV/div, 10 ps/div)* *(b) Output waveform (150 mV/div, 10 ps/div)*

*Figure 14*

*Input and output waveforms with pre-emphasis OFF (20 Gbit/s)*

Next, Figure 15 shows the output waveform when a 2 Post/1Pre-cursor emphasis waveform is input. The Eye opening becomes 152 mVp-p, which is 5.6 dB better than at 10 GHz with emphasis OFF.



*(a) Input waveform (400 mV/div, 10 ps/div)* *(b) Output waveform (150 mV/div, 10 ps/div)*

*Figure 15*

*Input and output waveforms at 2Post/1Pre-cursor (20 Gbit/s)*

## 5. How to Find Ideal Emphasis Setting

The previous section explained the cause of reduced signal integrity and pre-emphasis transmission technology to clarify the effectiveness of pre-emphasis transmission in suppressing drops in signal integrity. However, since emphasis setting parameters become more complex as transmission speed increases, it can be extremely difficult to find the ideal settings from the many possibilities. One method is to search for the ideal settings while verifying the output waveform, but this method takes an extremely long time and it is hard to come up with a rational explanation of why those settings are ideal. Consequently, it would be better to find a rational method of determining the ideal emphasis settings from the many complex possibilities. If we can find the ideal emphasis setting automatically, we could simplify and shorten the emphasis setting procedure, helping cut measurement and design verification times.

A way to achieve this goal is to add the inverse characteristics of the DUT frequency characteristics measured using a vector network analyzer (VNA) to the input signal as emphasis settings. In other words, letting the DUT transfer function be *H(f)* and the ideal emphasis transfer function be;

$$G(f)\cdot H(f)=1 \quad \text{(Eq. 1)}$$

or

$$G(f)=H^{-1}(f) \quad \text{(Eq. 2)}$$

we can obtain the ideal Eye opening. Accordingly, the ideal emphasis settings are calculated by finding the characteristics of the ideal emphasis circuit for DUT frequency characteristics up to 10 GHz as shown in Figure 16, or in other words, from the inverse characteristics of the DUT frequency characteristics.

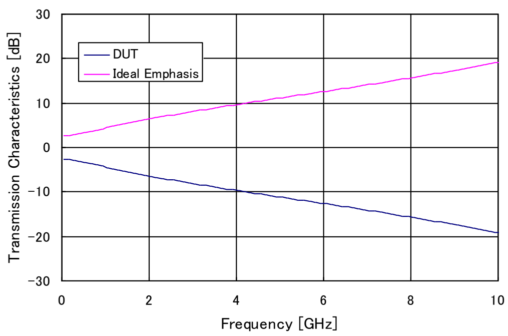



*Figure 16*

*DUT frequency characteristics and ideal emphasis frequency characteristics*

The MP1825B 4 Tap Emphasis and the MX210002A Transmission Analysis Software can be used to automatically find the ideal emphasis settings by determining the reverse characterstics of the DUT (Figures 17 and 18).

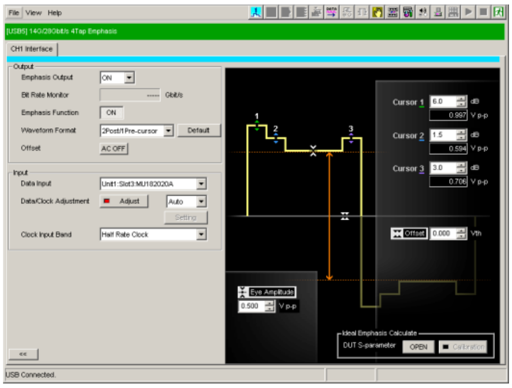


*Figure 17*

*MP1825B 4 Tap Emphasis*

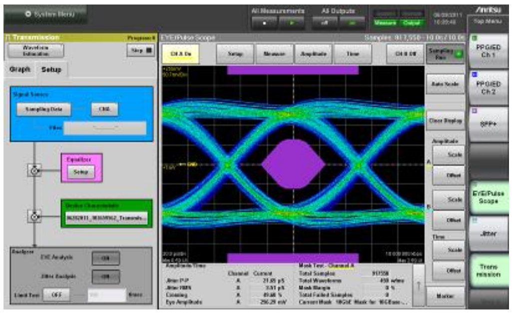
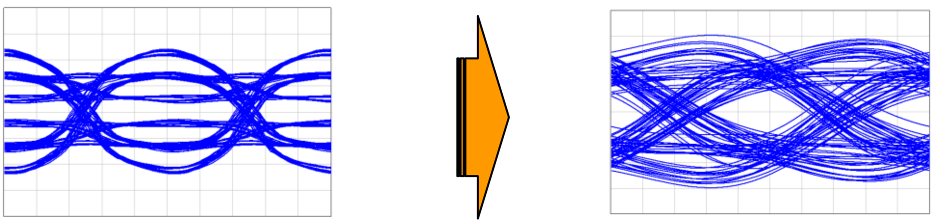


*Figure 18*

*MX210002A Transmission Analysis Software*

Using these two products, the ideal emphasis value is found by loading the frequency characteristics data (S parameter data) acquired using the VNA.

Using the previously described 27-inch backplane board (Figures 11 and 12) with a 20 Gbit/s pseudorandom pattern, when the ideal emphasis value is calculated with the MP1825B 4 Tap Emphasis, Cursor 1 becomes +7.8 dB, Cursor 2 becomes –4.9 dB and Cursor 3 becomes +10.9 dB. From these results, the Eye opening after passage through the 27-inch backplane board becomes 257 mVp-p (Figure 9) and we can see the that ideal emphasis settings have been obtained automatically.



*(a) Input waveform (400 mV/div, 10 ps/div)*

*(b) Output waveform (150 mV/div, 10 ps/div)*

*Figure 19*

*Input and output waveforms with ideal emphasis setting*

## 6. Conclusion

As transmission speeds increase to 25.8 and 28 Gbit/s, there are increasing demands for product size reductions, lower power consumption and lower costs, and maintaining signal integrity is becoming ever more difficult. In these circumstances, Anritsu must provide solutions securing signal integrity and shortening design and test periods.

This article explains emphasis technology as one method for correcting transmission losses. Transmission loss is a problem that always occurs when a signal passes along a transmission path. Pre-emphasis is the most effective technology for suppressing these transmission losses. Anritsu's MP1825B 4 Tap Emphasis and MX210002A Transmission Analysis Software solutions provide an algorithm for capturing the DUT frequency characteristics and outputting the ideal emphasis settings. The ideal emphasis settings found from the many setting parameters can be set automatically to assure better quantitative signal integrity in the shortest time.

Faster transmission speeds demand both technologies assuring signal integrity and design margins while meeting the growing technical challenges for smaller size, lower power and cost reductions.

Anritsu's is dedicated to providing on-time solutions for customers facing these types of challenges.

Specifications are subject to change without notice.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