Application Note

Adjusting MIMO Phase Coherence using Vector Signal Generator

MG3710A

Vector Signal Generator

Introduction

MIMO (Multi-Input Multi-Output) is one technology for improving the speed and quality of wireless data transfers. It is used by many wireless standards, including LTE, wireless LAN, WiMax, etc. Previously, MIMO was the mainstream technology for downlink connections between the base stations and transmitters, as well as between terminals and receivers. Recently, in response to increasing data transmission volumes, MIMO is also being used for uplinks in IEEE802.11n and LTE-Advanced systems. Its application range is expected to widen in the future and more problems are to be expected.

This application note explains how to synchronize RF signals between multiple channels when simulating a MIMO transmitter by using Anritsu's MG3710A Vector Signal Generator.

The MIMO evaluation system described in this application note requires installation of the following options and firmware in the MG3710A Vector Signal Generator.

1stRF (Select one.)
- 1stRF 100 kHz to 2.7 GHz [MG3710A-032]
- 1stRF 100 kHz to 4 GHz [MG3710A-034]
- 1stRF 100 kHz to 6 GHz [MG3710A-036]

2ndRF (Select one.)
- 2ndRF 100 kHz to 2.7 GHz [MG3710A-062]
- 2ndRF 100 kHz to 4G Hz [MG3710A-064]
- 2ndRF 100 kHz to 6 GHz [MG3710A-066]

Universal Input/Output [MG3710A-017] (requires in case of synchronization multiple MG3710As)

Firmware Ver. 2.02.00 and later

MIMO Outline

MIMO technology sends and receives different data using multiple antennas. Increasing the number of antennas in the data transfer path offers the ability to increase data transfer per unit time. A system with two sending (Tx) and two receiving (Rx) antennas is called 2x2 MIMO, and, similarly, a system with four Tx and four Rx antennas is called 4x4 MIMO.

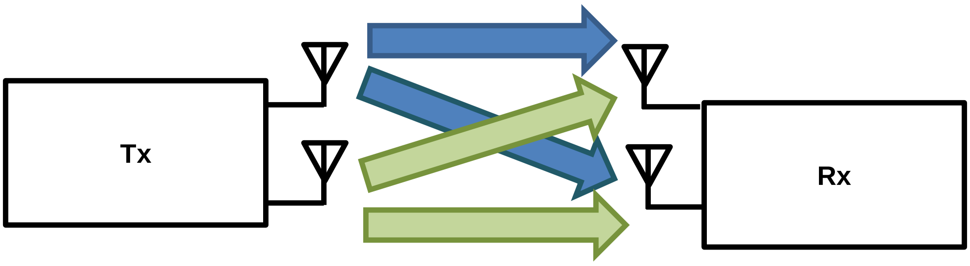

Figure 1. 2x2 MIMO conceptual diagram

The transmitter creates a stream of data for the number of MIMO channels. Then, parallel processing is performed on the created data stream. The same parallel processing is used at both the transmitter and receiver so mixed-channel signals received at each antenna of the receiver can be separated from one another. Each of the parallel-processed data streams is sent from the corresponding antenna; the receiver antennas receive the mixed signals from each of the transmitter antennas, and perform reverse parallel processing to the parallel processing used at the transmitter to separate the mixed signals and recreate the original data stream.

In general MIMO technology, the carrier frequency of the RF signal used between each channel is the same as the bandwidth and the phase and timing at sending are also synchronized. However, due to the distance between antennas in the wireless area as well the presence of interfering objects, such as buildings, the signals may be attenuated and delayed, causing frequency and amplitude/phase errors at the receiver antennas. The receiver corrects these errors using equalizing, etc., to recover the original data.

In the same way, when simulating a MIMO transmitter using several signal generators, it may sometimes be necessary to synchronize the phase and timing between RF signals.
If the functions and performance of a MIMO receiver can be tested by adding known phase and timing errors to the sent baseband signal, the receiver performance can be evaluated for the transmission path characteristics using a fading simulator.

Achieving Phase Coherence

When the phase and timing between RF signals are synchronized, there is a fixed phase difference (offset) between the RF signals. This is called the phase coherence.

Figure 2 shows the simplified block diagram for a wireless transmitter using the direct conversion method.
The primary modulated digital data is converted to the analog I/Q signal using the D/A converter in the baseband section. The analog I/Q signal is converted to the RF signal by direct conversion.

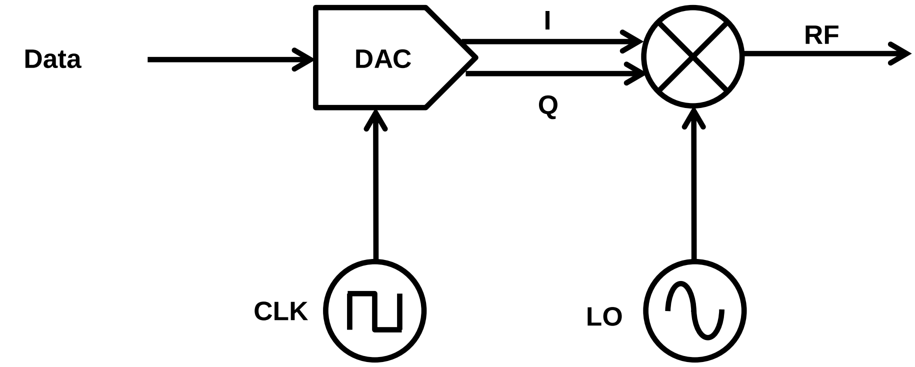

Figure 2. Structure of wireless transmitter using direct conversion

Figure 3 shows the block diagram for achieving phase coherency based on the structure shown in Figure 2.
To achieve phase coherency, it is necessary to share the start timing for sending data, the local oscillator (LO), and the sampling clock (CLK) for the baseband signal between channels.

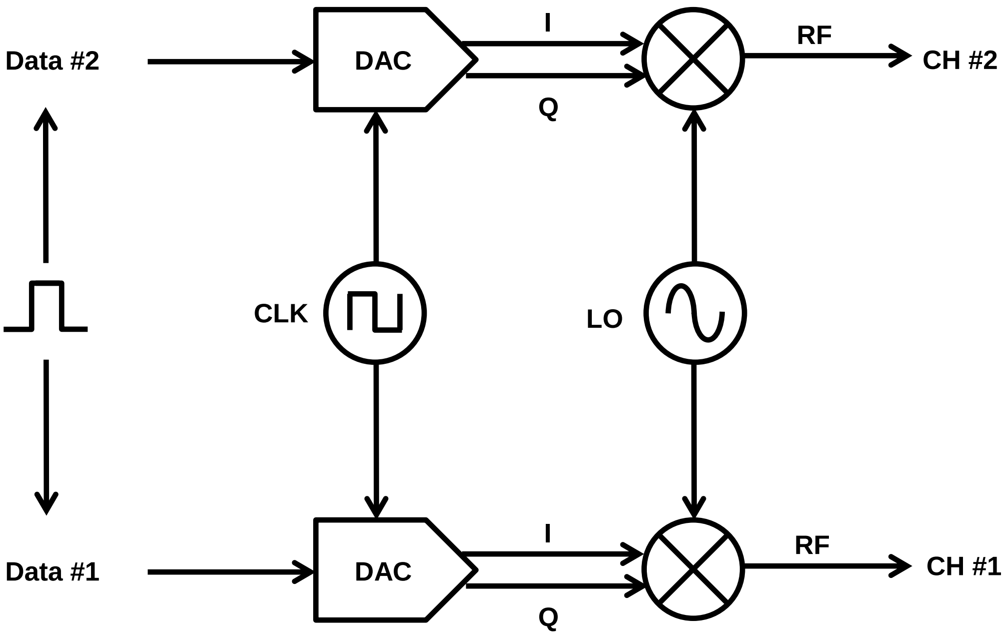

Figure 3. Synchronization between channels

2x2 MIMO

The Anritsu MG3710A Vector Signal Generator can be configured with two RF options and by using this instrument, the blocks can be configured easily as shown in Figure 4 using the signal generator synchronization function.

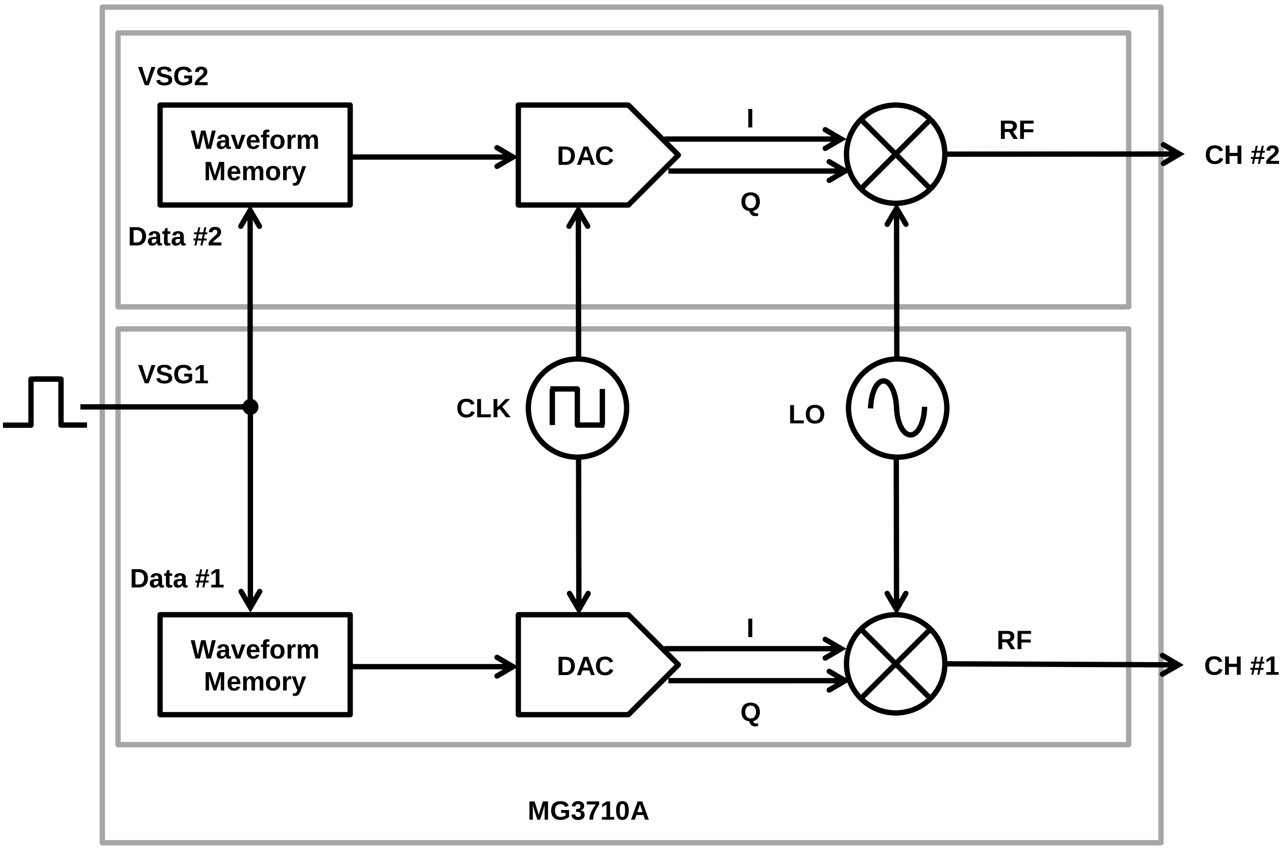

Figure 4. Channel synchronization using MG3710A SG

This application note explains how to minimize phase and timing errors between RF signals using a spectrum analyzer. In this method, combining 180° out-of-phase signals cancels out the positive and negative amplitudes, minimizing the power.

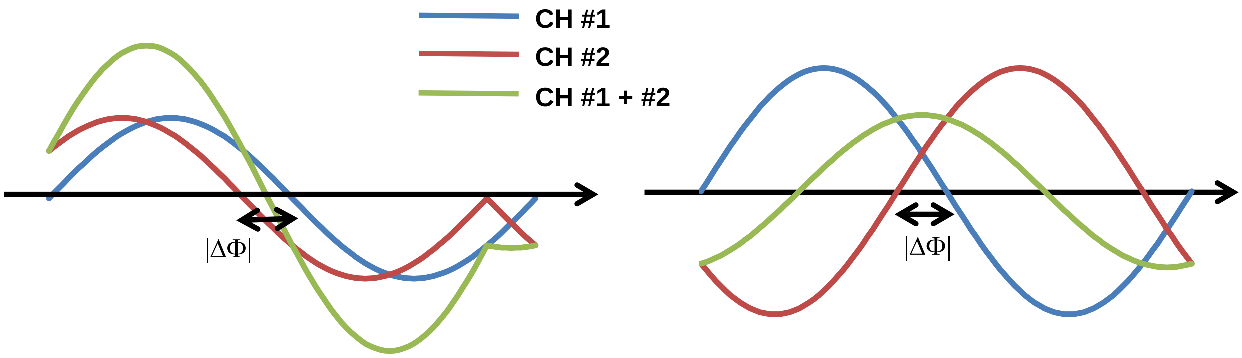

Figure 5. Waveforms of two signals to be synchronized; phase error |ΔΦ| (left) and phase error 180°+ |ΔΦ| (right)

Figure 6 shows the configuration of the measurement system. When connecting VSG1 and VSG2 to the combiner, use cables of the same length and type.

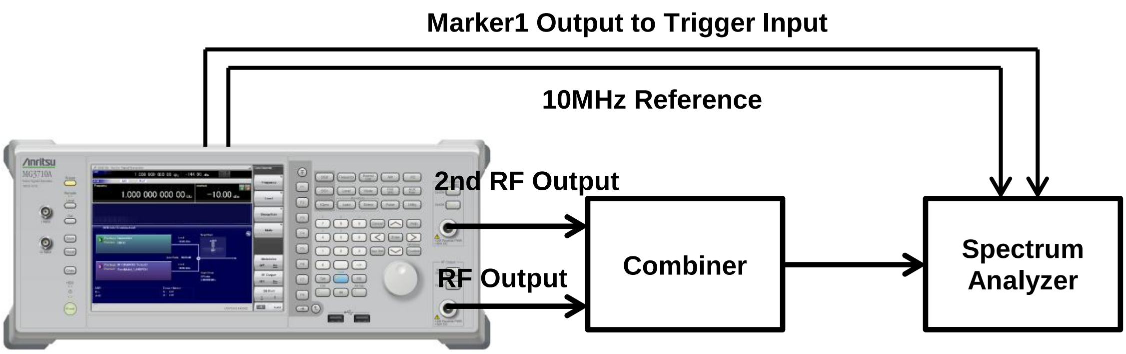

Figure 6. 2x2 MIMO configuration

Next, this application note explains adjustment of the phase and timing based on VSG1.

2x2 MIMO (continued)

[Adjustment Procedure]

1. Press [Preset] → [F1: Preset] to perform initialization.

2. At both VSG1 and VSG2, load the [Adjustment] waveform pattern of the [Phase Coherence] package.

3. Press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] to display the Sync Multi SG function menu.
   -1. Press [F1: Sync Type] and select [F4: SG1&2].
   -2. Set [F4: LO Sync] to On.

4. Set the following parameters to the same values at both the VSG1 and VSG2.

Frequency	Any value (but same at both VSG1 and VSG2)
Amplitude	Any value (but same between channels)
Modulation	On
RF Output	On

5. At both VSG1 and VSG2:
   -1. Press [Cal] → [F2: I/Q Cal] to display the I/Q Calibration function menu.
   -2. Set [F2: Cal Type] to DC.
   -3. Press [F1: Execute] to perform I/Q DC Cal.

6. Set the following parameters to the same values at both the VSG1 and VSG2.
   ATT Hold[Note1] On

7. At VSG1, press [Mode] → [→] (page 2 of function menu) → [F4: Marker Setup] → [F1: Marker1 A] and set

[F1] Edit Mode	Sync
[F2] Offset	0.00
[F3] Width	10.00

8. At VSG1,
   press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] and set [F2: Mode] to Start.
   press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] and set [F3: Source] to Trigger Key.

9. At VSG1, press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] → [F8: Trigger Key]

   Figure 7 shows the spectrum analyzer status at this instant before phase adjustment.

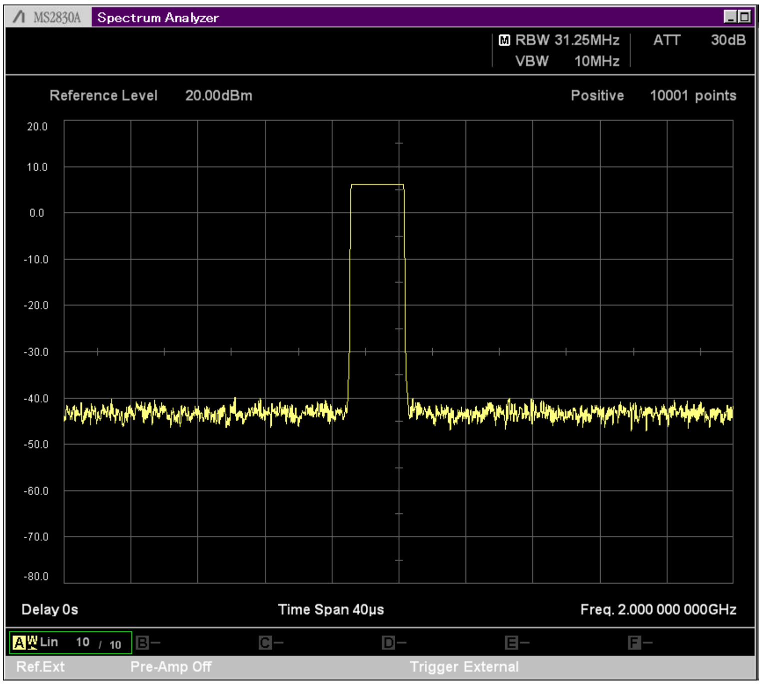

Figure 7. Status before phase adjustment

10. At VSG1, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to minimize the level measured by the spectrum analyzer.

Figure 8 shows the spectrum analyzer at this time instant.

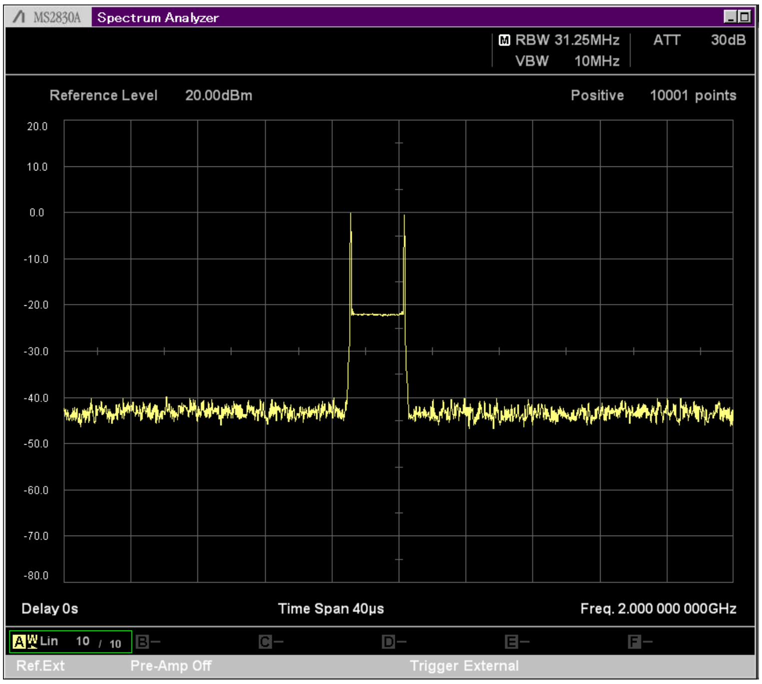

Figure 8. Status after first phase adjustment

11. At VSG2, press [Level] and adjust the output level to minimize the level measured by the spectrum analyzer.

    Figure 9 shows the spectrum analyzer at this time instant.

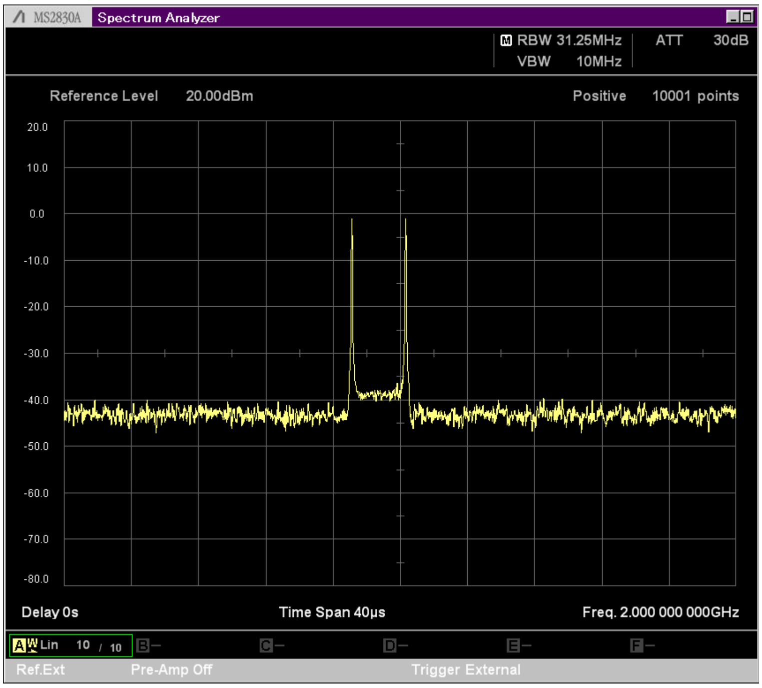

Figure 9. Status after level adjustment

12. At VSG2, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to minimize the level measured by the spectrum analyzer.

Figure 10 shows the spectrum analyzer at this time instant.

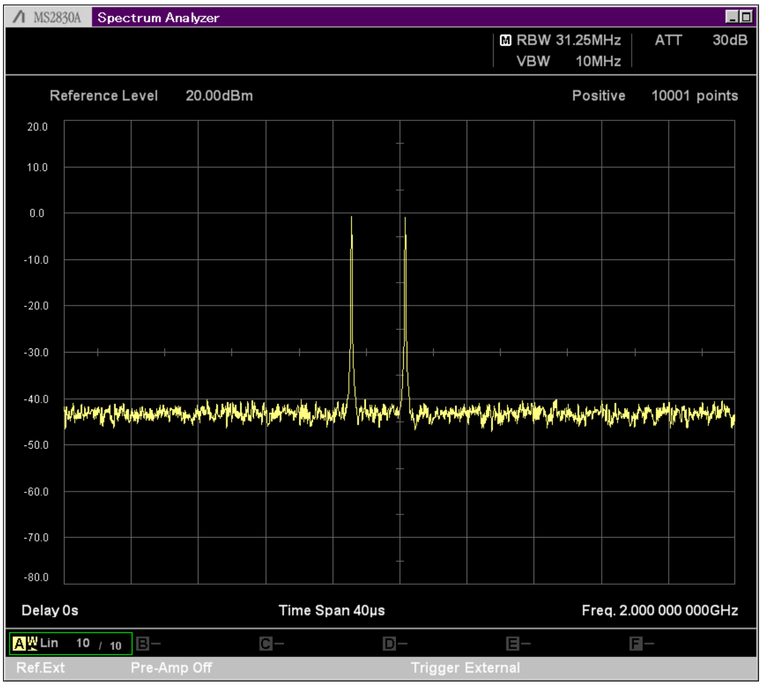

Figure 10. Status after second phase adjustment

13. At VSG2, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F8: I/Q Delay] to minimize the level measured by the spectrum analyzer.

    Figure 11 shows the spectrum analyzer at this time instant.

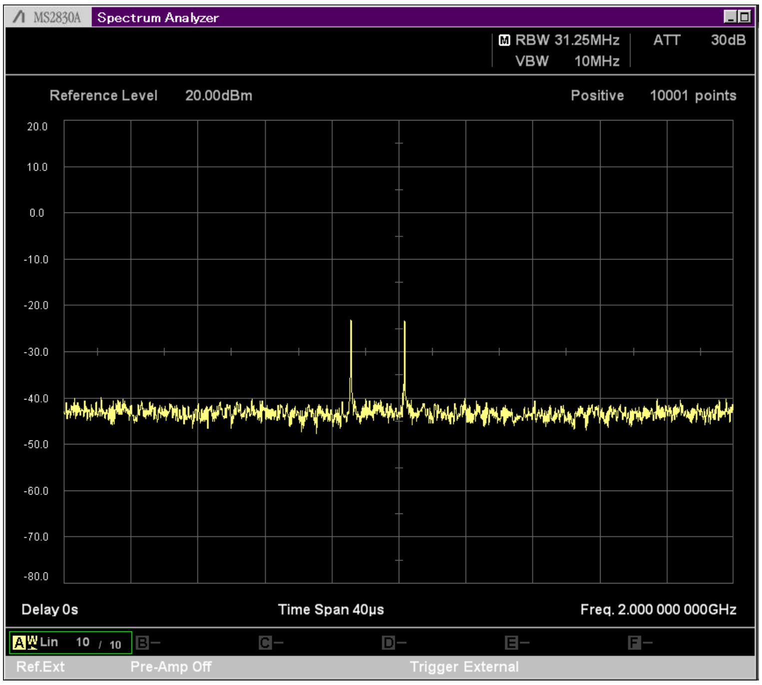

Figure 11. Status after timing adjustment

At this point in time, the phase error of the signal outputs from VSG1 and VSG2 is 180°+|ΔΦ|.

14. At VSG2, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and set the value of [F7: I/Q Phase] by adding 180° to the current setting. For example, when 10° is set at step 10, set 180° + 10° = 190°. If the value is over 360°, the value will be 180° decreased.

At this instant, the phase error of the signals output from VSG1 and VSG2 becomes the minimized value ΔΦ.

15. At VSG1, load the waveform data for channel #1.

16. At VSG2, load the waveform data for channel #2.

17. At VSG1, press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] → [F8: Trigger Key]

By these procedures, selected waveform signals from both VSG1 and VSG2 output with stable and minimum difference in phase and time.

Note1:

The Anritsu MG3710A Vector Signal Generator optimizes the signal path by setting the frequency and level to obtain the highest performance under every setting condition. As a result, if the frequency and level settings are changed after having adjusted the phase and timing between channels, it is necessary to readjust the phase and timing again. However, if the [ATT Hold] parameter is set to On, the signal path does not change even if the level is changed.

4x4 MIMO

Two units of the MG3710A are required for 4x4 MIMO and the measurement system is configured as shown in Figure 12. Since all the send data start timing, LO between channels and sampling clocks for basebands must be shared between the four channels, these signals must be shared between the two vector signal generators.

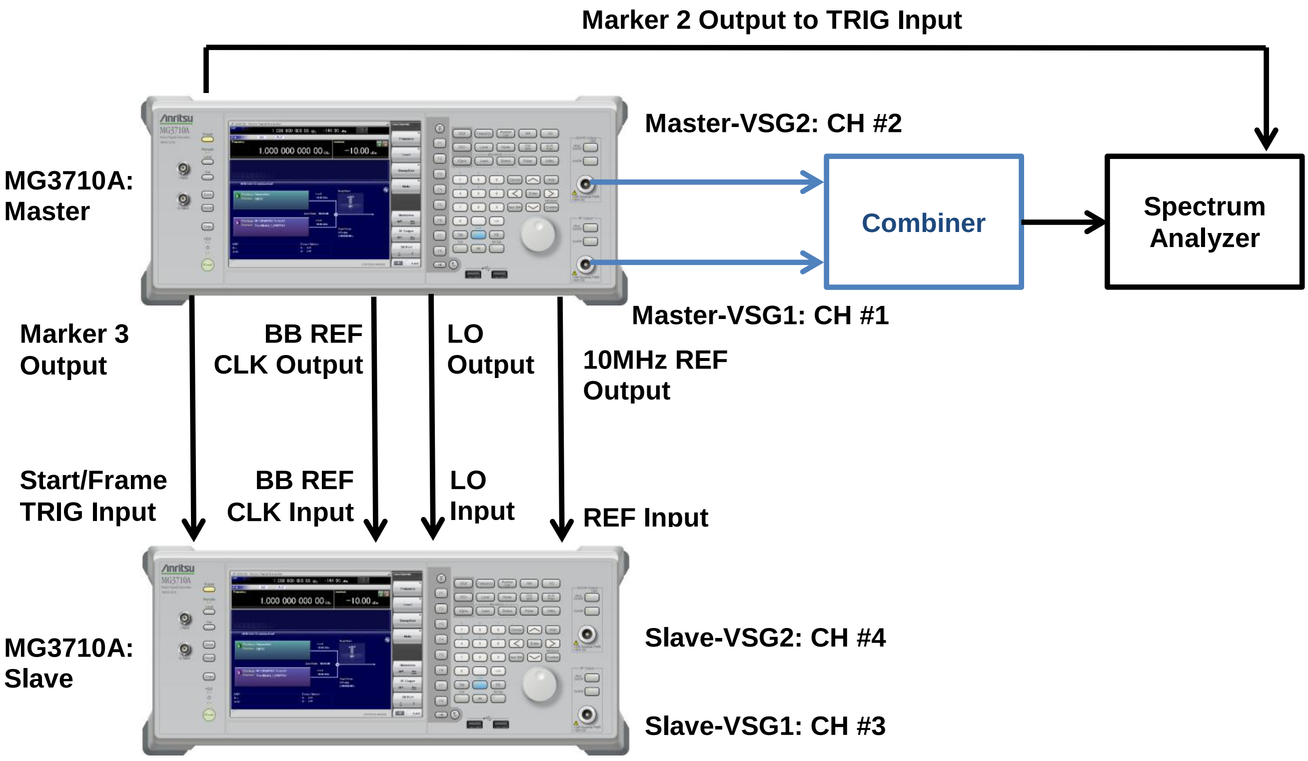

Figure 12. 4x4 MIMO configuration
(Connection between Combiner and Spectrum Analyzer is for adjustment to VSG1 and VSG2 in master MG3710A)

Increasing the number of shared channels also increases the phase and timing error adjustment procedures between channels. The procedure for 4x4 MIMO is described below. In this description, the phase and timing of other channels are adjusted based on VSG1 of the master MG3710A.

Step 1: Adjusting Phase difference between Master VSG1 and Master VSG2

1. Combine the RF outputs of VSG1 and VSG2 of the master MG3710A using the combiner and input the combined outputs to the spectrum analyzer.

2. At both the master and slave MG3710A, press [Preset] → [F1: Preset] to perform initialization.

3. At both VSG1 and VSG2 of the master MG3710A and at VSG1 and VSG2 of the slave MG3710A, load the [Adjustment] waveform pattern of the [Phase Coherence] package.

4. At the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] to display the Sync Multi SG function menu.
   -1. Press [F1: Sync Type] and select [F2: Master].
   -2. Set [F4: LO Sync] to On.

5. Set the following parameters to the same values at both VSG1 and VSG2 of the master MG3710A:

Frequency	Any value (but same value between channels)
Amplitude	Any value (but same value between channels)
Modulation	On
RF Output	On

6. At both VSG1 and VSG2 of the master MG3710A:
   -1. Press [Cal] → [F2: I/Q Cal] to display the I/Q Calibration function menu.
   -2. Set [F2: Cal Type] to DC.
   -3. Press [F1: Execute] to perform I/Q DC Cal.

7. Set the following parameters to the same values at both the VSG1 and VSG2 of the master MG3710A.
   ATT Hold[Note1] On

8. At VSG1 of the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F4: Marker Setup] → [F1: Marker2 A] and set

[F1] Edit Mode	Sync
[F2] Offset	0.00
[F3] Width	10.00

9. At VSG1 of the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F4: Marker Setup] → [F1: Marker3 A] and set

[F1] Edit Mode	Sync
[F2] Offset	0.00
[F3] Width	10.00

10. At VSG1 of the master MG3710A,
    press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] and set [F2: Mode] to Start.
    press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] and set [F3: Source] to Trigger Key.

11. At VSG1 of the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] → [F8: Trigger Key]

12. At VSG2 of the master MG3710A:
    -1. Press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to minimize the measured level at the spectrum analyzer.
    -2. Press [Level] and adjust the output level to minimize the measured level at the spectrum analyzer.
    -3. Again, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and readjust [F7: I/Q Phase] to minimize the measured level at the spectrum analyzer.

13. At VSG2 of the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F8: I/Q Delay] to minimize the measured level at the spectrum analyzer.

14. At VSG2 of the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to add 180° to the current setting. If the value is over 360°, the value will be 180° decreased.

Step 2: Adjusting Phase difference between Master VSG1 and Slave VSG1

15. Combine the RF outputs of VSG1 of the slave and master MG3710A using the combiner and input the combined outputs to the spectrum analyzer.

16. At the slave MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] to display the Sync Multi SG function menu.
    -1. Press [F1: Sync Type] and select [F2: Slave].
    -2. Set [F4: LO Sync] to On.

17. Set the following parameters to the same values at both VSG1 and VSG2 of the slave MG3710A:

Frequency	Any value (but same value between channels)
Amplitude	Any value (but same value between channels)
Modulation	On
RF Output	On

18. At both VSG1 and VSG2 of the slave MG3710A:
    -1. Press [Cal] → [F2: I/Q Cal] to display the I/Q Calibration function menu.
    -2. Set [F2: Cal Type] to DC.
    -3. Press [F1: Execute] to perform I/Q DC Cal.

19. Set the following parameters to the same values at both the VSG1 and VSG2 of the slave MG3710A.
    ATT Hold[Note1] On

20. At VSG1 of the slave MG3710A, press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] and set [F2: Mode] to Start.

21. At VSG1 of the slave MG3710A:
    -1. Press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to minimize the measured level at the spectrum analyzer.
    -2. Press [Level] and adjust the output level to minimize the measured level at the spectrum analyzer.
    -3. Again, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and readjust [F7: I/Q Phase] to minimize the measured level at the spectrum analyzer.

22. At VSG1 of the slave MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F8: I/Q Delay] to minimize the measured level at the spectrum analyzer.

23. At VSG1 of the slave MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to add 180° to the current setting. If the value is over 360°, the value will be 180° decreased.

Step 3: Adjusting Phase difference between Master VSG1 and Slave VSG2

24. Combine the RF outputs of VSG1 of the master MG3710A and VSG2 of the slave MG3710A using the combiner and input the combined outputs to the spectrum analyzer.

25. At VSG2 of the slave MG3710A:
    - -1. Press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to minimize the measured level at the spectrum analyzer.
    - -2. Press [Level] and adjust the output level to minimize the measured level at the spectrum analyzer.
    - -3. Again, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and readjust [F7: I/Q Phase] to minimize the measured level at the spectrum analyzer.

26. At VSG2 of the slave MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Delay: to minimize the measured level at the spectrum analyzer.

27. At VSG2 of the slave MG3710A, press [Mode] → [→] (page 2 of function menu) → [F8: Sync Multi SG] and adjust [F7: I/Q Phase] to add 180° to the current setting. If the value is over 360°, the value will be 180° decreased.

At this instant, the phase error of the RF signal between the 4 channels is minimized.

28. At VSG1 of the master MG3710A, load the waveform data for channel #1.

29. At VSG2 of the master MG3710A, load the waveform data for channel #2.

30. At VSG1 of the slave MG3710A, load the waveform data for channel #3.

31. At VSG2 of the slave MG3710A, load the waveform data for channel #4.

32. At VSG1 of the master MG3710A, press [Mode] → [→] (page 2 of function menu) → [F2: Start/Frame Trigger] → [F8: Trigger Key] to begin synchronization.

By these procedures, selected waveform signals from both VSG1 and VSG2 of both of the master and slave MG3710A output with stable and minimum difference in phase and time.

Note1:

The Anritsu MG3710A Vector Signal Generator optimizes the signal path by setting the frequency and level to obtain the highest performance under every setting condition. As a result, if the frequency and level settings are changed after having adjusted the phase and timing between channels, it is necessary to readjust the phase and timing again. However, if the [ATT Hold] parameter is set to On, the signal path does not change even if the level is changed.

Summary

At MIMO system evaluation, it may sometimes be necessary to achieve strict phase coherence between multiple RF signals. Anritsu's MG3710A Vector Signal Generator makes this operation easy with simple configuration of a MIMO evaluation system.

Note

Specifications are subject to change without notice.

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