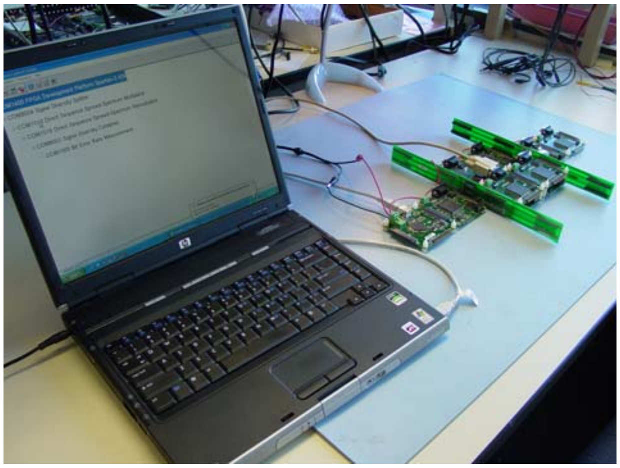
APPLICATION NOTE: SIGNAL DIVERSITY COMBINING USING COMBLOCKS

Overview

Signal diversity combining is a basic technique to enhance the reliability of communication links. This note presents several applications of signal diversity combining using the ComBlock family of rapid prototyping modules.

At the heart of each application are the COM-8003 signal diversity combiner and COM-8004 signal diversity splitter modules.

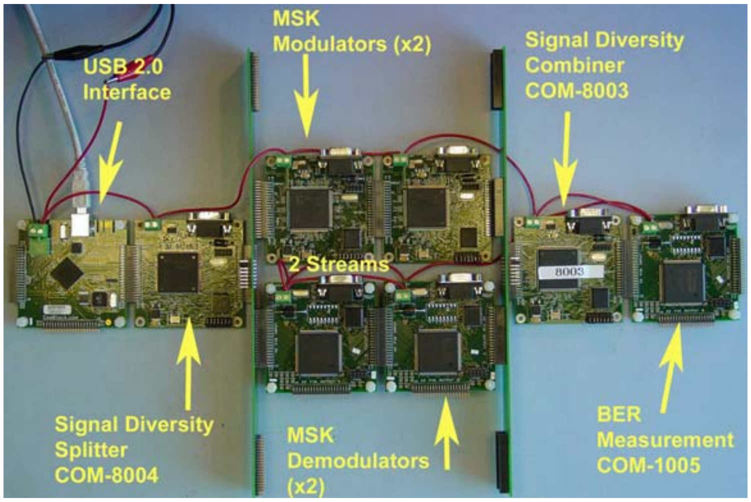


Signal Diversity Test setup

Time Diversity for Mobile Broadcast

The reliability of a mobile broadcast system can be significantly increased by using ***time diversity***: at least two time-delayed replica of the information are transmitted towards mobile users. This way, if a signal path is temporarily blocked, the user receiver can still reconstruct the uninterrupted original signal.

In the testbed shown below, a 6 Mbit/s broadcast signal is split into two replica. One replica is delayed 22 seconds with respect to the original signal. Both replica are MSK modulated and transmitted over independent channels. On the mobile user side, the two replica are demodulated, re-aligned, and combined.



Time-Diversity Test Bed

A several second long blockage is created at the mobile user end, mimicking the effect of driving under a bridge while receiving a satellite broadcast.

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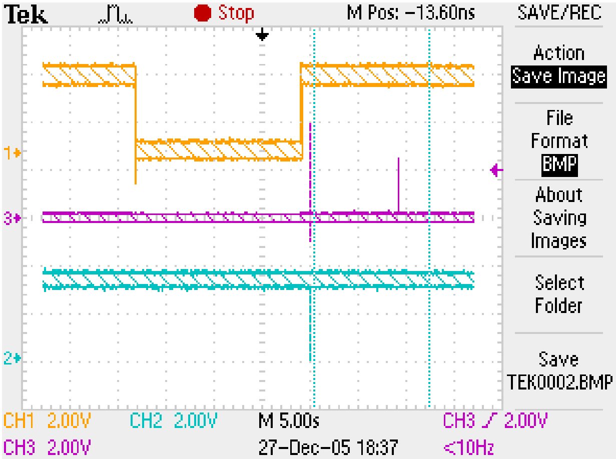
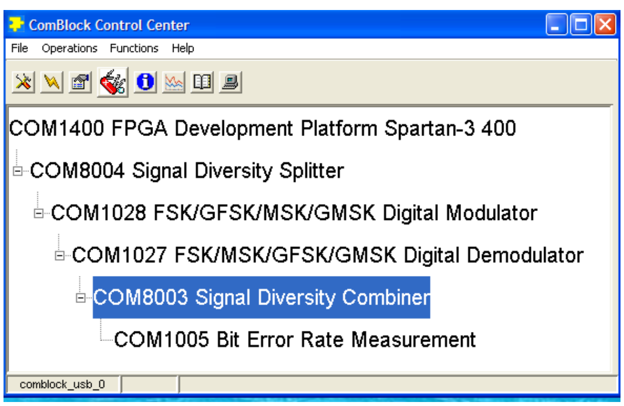


Oscilloscope capture
Orange trace: Input signals present
Purple trace: bit errors after combining
Teal trace: BER measurement lock status

This test demonstrates that no signal interruption occurred at the combiner output despite both input signals being blocked simultaneously for 17 seconds. A few (4346) bit errors occurred, an insignificant number over the 300 Mbits transmitted during the oscilloscope capture. These errors can easily be removed using conventional interleaver and forward error correction techniques.



Time Diversity Test Bed Monitoring & Control

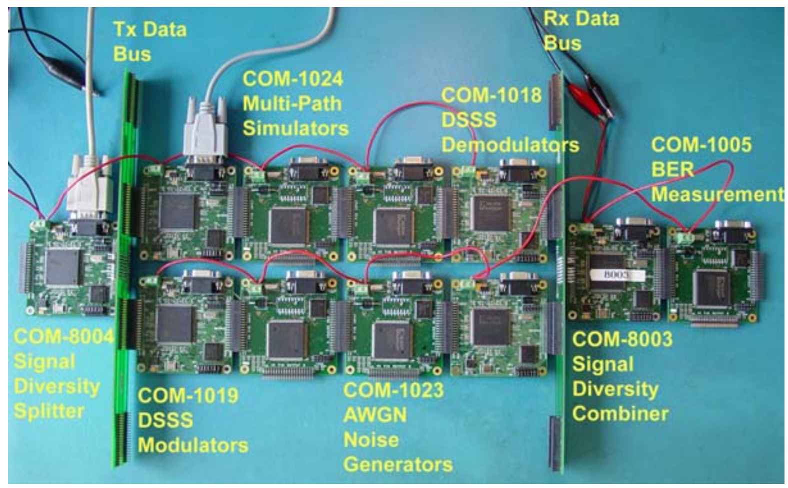
The testbed can be controlled and monitored remotely using the ComBlock Control Center graphical user interface.

Details of the ComBlock configuration can be found in Appendix A.

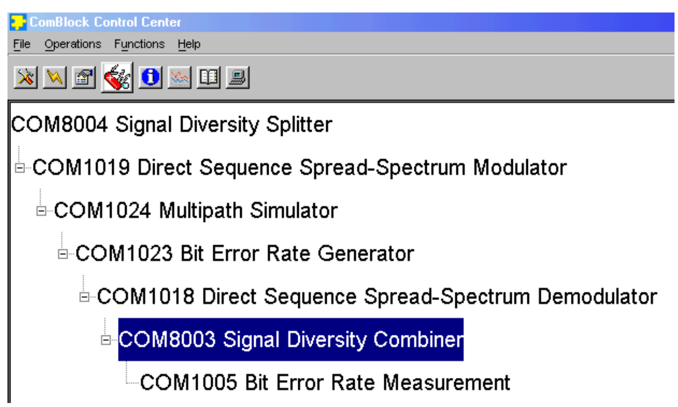
SNR Improvement

Signal to noise ratio can be improved by using ***spatial diversity*** combining. A typical application is a mobile user transmitting with an omni-directional antenna, the signal being received by two spatially separated receivers, then combined coherently.

The testbed shown below was configured to demonstrate the benefits of spatial diversity combining. A 312 Kbit/s Direct-Sequence Spread-Spectrum BPSK signal is received over two receivers. Each received signal is equally affected by Additive White Gaussian Noise. For a single stream BER of 1.09 10^{-2}, the BER becomes 4.8 10^{-4} after combining, reflecting a 3 dB improvement in SNR.

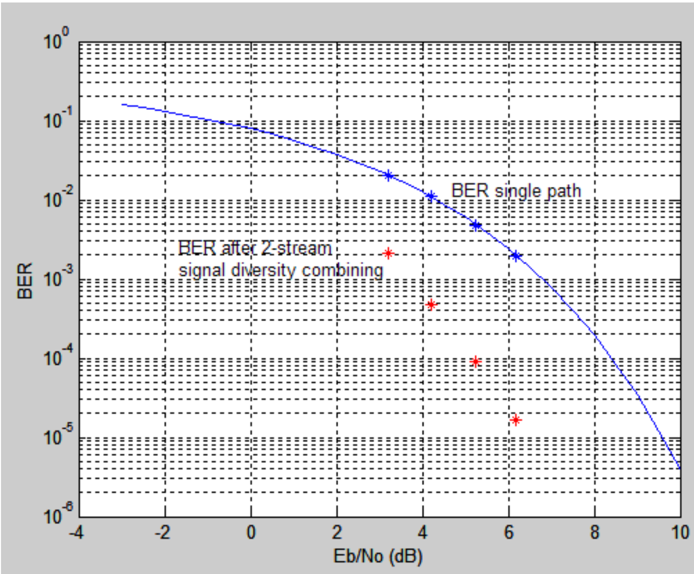


Spatial-Diversity Test Bed



Spatial Diversity Test Bed Monitoring & Control

The relationship between single-stream BER and BER after combining is illustrated below.



3 dB SNR improvement through 2-stream signal diversity combining. Blue trace: single stream, Red trace: after 2-stream combining.

Details of the ComBlock configuration can be found in Appendix B.

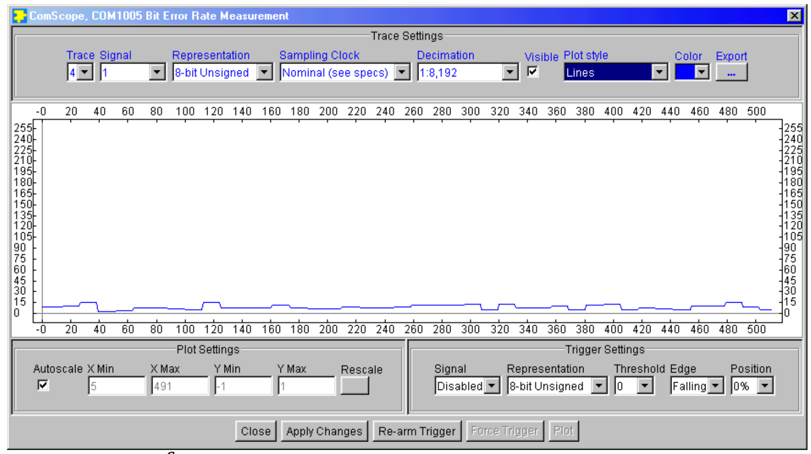
Multi-Path Mitigation

Statistically, multi-path fading is less likely to cause link interruptions when multiple spatially-separated receivers are used in conjunction with a combiner. The testbed below illustrates the benefits of combining two signals received over a simple Rician fading channel.

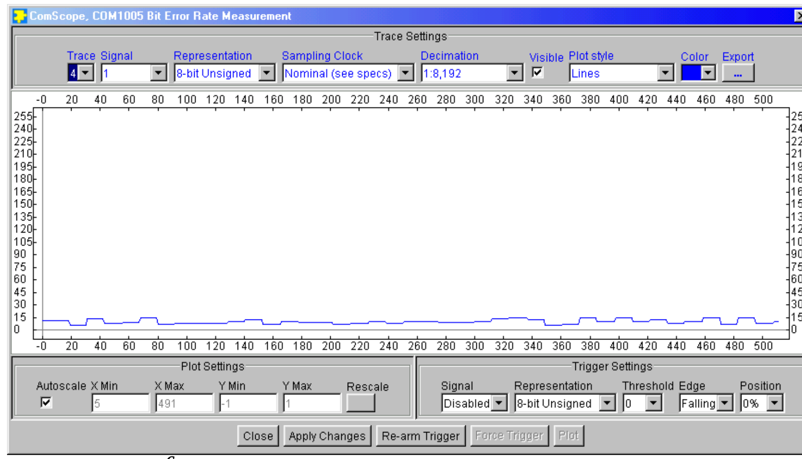
Two receivers are used, each receiving the direct line-of-sight signal plus a signal resulting from an indirect path. The indirect path signal is -12 dB lower in power, offset in frequency by 74 Hz/148 Hz and delayed by 50 m / 100 m.

The transmitted signal is a 312 Kbit/s Direct-Sequence Spread-Spectrum Signal using a length 13 Barker spreading code at 4 Mchips/s.

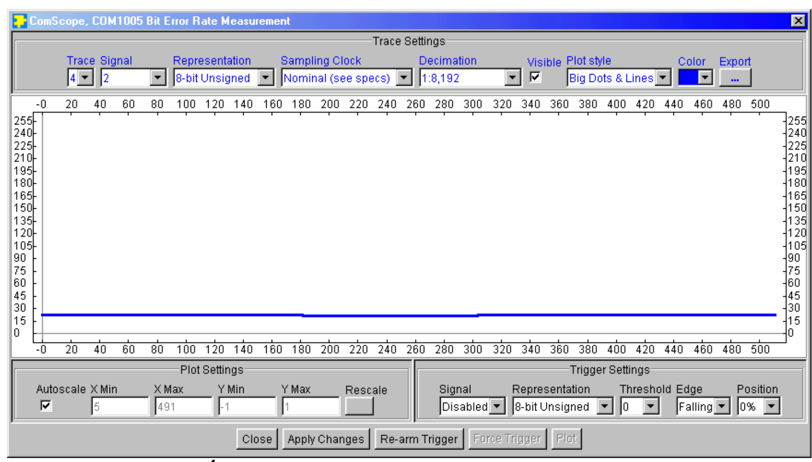
The BER captures are shown below.



BER/10^{-6} after 2-stream combiner, AWGN noise only, no multi-path.



BER/10^{-6} after 2-stream combiner, AWGN noise and simple Rician fading channel.



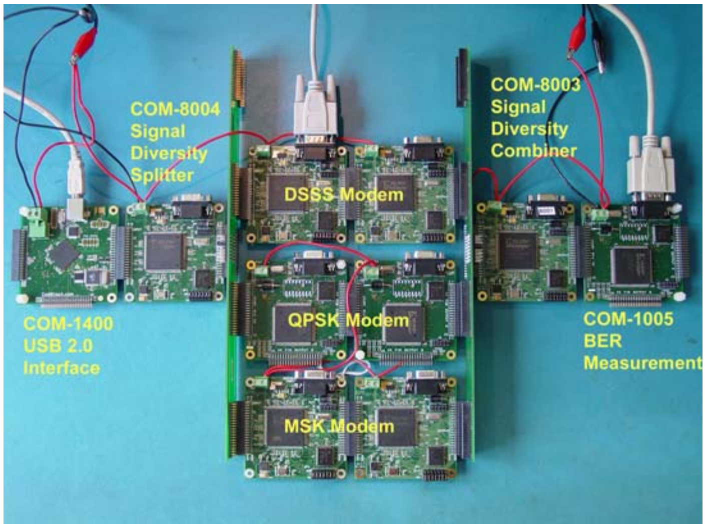
BER/2.56 10^{-4} single stream (no combiner), AWGN noise and simple Rician fading channel.

Details of the ComBlock configuration can be found in Appendix C.

Modulation Diversity

The selected combining technique aggregates received signals after demodulation. Consequently, the technique is not sensitive to modulation. It can therefore be used as part of a modulation-diversity system as demonstrated in the testbed shown below.

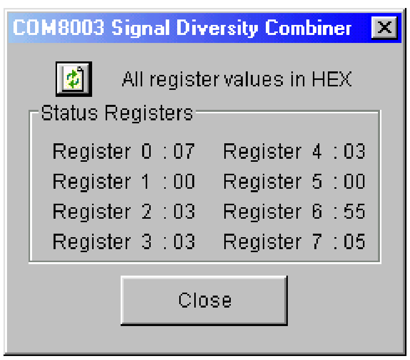
Three signal replica are transmitted using three distinct modulation schemes: QPSK, Direct-Sequence Spread-Spectrum QPSK and MSK. Proper operation requires that all modulators derive their symbol rate from a common clock and that all modulators bit rates be strictly identical.



Modulation-Diversity Test Bed

The COM-8003 receives three demodulated soft-quantized streams from the three demodulators, compensates for differential delays and combines the re-aligned streams.

Monitoring of the COM-8003 shows that the combiner recovers the synchronization for all three streams, that it detects the same Noise-to-Signal ratio (03) on all three streams and that it applies the same scaling coefficients (5) on all three streams prior to combining.



COM-8003 Monitoring Status

Details of the ComBlock configuration can be found in Appendix D.

Appendix A

The Time Diversity testbed consists of the following ComBlock modules:

COM-8003 Signal Diversity Combiner
COM-8004 Signal Diversity Splitter
COM-1027 FSK/MSK demodulator
COM-1028 FSK/MSK/GFSK/GMSK modulator
COM-1005 BER Measurement
COM-1400 USB 2.0 interface.

A pseudo-random binary data stream (PRBS-11) is generated as a test sequence within the COM-8003.

Two replica are generated, one of them delayed by 22.4 seconds, the other not subject to any delay. Each stream is forwarded to a distinct COM-1028 MSK modulator configured for a 6 Mbit/s bit rate. Both COM-1028 modulators use the same external 40 MHz clock reference in order to operate at exactly the same bit rate.

On the receiver side, two independent COM-1027 MSK demodulators retrieve the two independent streams. The Role of the COM-8003 combiner is re-align both demodulated streams by applying a delay to the early replica.

Configuration: 6Mbit/s MSK, streams 0 & 2
COM-8004: 05 04 00 00 00 20 00 00 00 00 00 00 00 00 00 01
COM-1028: 33 33 13 00 00 00 FF 80 00 00 83 02
COM-1027: 33 33 13 00 00 00 00 02 94 02
COM-8003: 05 04 00 20 00 00 00 00 00 00 00 28
COM-1005: 2C

Appendix B

The Spatial Diversity testbed consists of the following ComBlock modules:

COM-8003 Signal Diversity Combiner
COM-8004 Signal Diversity Splitter
COM-1019 DSSS modulator
COM-1018 DSSS demodulator
COM-1023 AWGN generator
COM-1024 Multi-path generator
COM-1005 BER Measurement

COM-1400 USB 2.0 interface.

Configuration: 4.064 Mchip/s, 312kbit/s DSSS modulation, BPSK, spreading factor 13, streams 0 & 2. RRC filters 40% rolloff.
COM-8004: 05 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
COM-1019: 3A 01 0D 0D 00 00 03 00 00 00 00 00 00 00 00 00 FF 00 83 1C 02
COM-1024: FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
COM-1023: 00 00 0A 06 20 00 00 00 00
COM-1018: 3A 01 0D 0D 00 00 03 00 00 00 00 00 00 00 00 00 82 E1 82
COM-8003: 05 04 00 00 00 00 00 00 00 00 00 10 02
COM-1005: 2C

A pseudo-random binary data stream (PRBS-11) is generated as a test sequence within the COM-8003.

Two data stream replica are generated and independently modulated through two Direct-Sequence Spread-Spectrum modulators. Two equal-power Additive White Gaussian Noise signals are summed with the DSSS modulated streams. Two independent demodulators recover the two streams prior to combining.

For simplicity, the channel impairements (AWGN, multi-path) are realistically generated in digital form at baseband: the analog signals are represented as 10-bit precision complex (I & Q) baseband samples at 40 Msamples/s.

Appendix C

The same Spatial Diversity testbed as described in Appendix B is used for simulating multi-path and the mitigation effect of signal diversity combining.

Configuration: 4.064 Mchip/s, 312kbit/s DSSS modulation, BPSK, Barker spreading code of length 13, streams 0 & 2. RRC filters 40% rolloff.
COM-8004: 05 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
COM-1019: 3A 01 0D 0D 00 00 03 00 00 00 00 00 00 00 00 00 FF 00 83 1C 02
COM-1024: FF FF 00 40 00 00 00 00 00 00 0F 00 00 00 0F 00 00 00 00 00 00 00 00 00 00 00 00
COM-1023: 00 00 0A 06 1C 00 00 00 00
COM-1018: 3A 01 0D 0D 00 00 03 00 00 00 00 00 00 00 00 00 82 E1 82
COM-8003: 05 04 00 00 00 00 00 00 00 00 00 10 02
COM-1005: 2C

Appendix D

The Modulation Diversity testbed consists of the following ComBlock modules:

COM-8003 Signal Diversity Combiner
COM-8004 Signal Diversity Splitter
COM-1019 DSSS modulator
COM-1018 DSSS demodulator
COM-1027 FSK/MSK demodulator
COM-1028 FSK/MSK/GFSK/GMSK modulator
COM-1001 BPSK/QPSK/OQPSK demodulator
COM-1002 BPSK/QPSK/OQPSK emodulator
COM-1005 BER Measurement
COM-1400 USB 2.0 interface.

Configuration: 300 Kbit/s modulation on all three streams.
Stream0: QPSK.
Stream1: DSSS QPSK, maximal length code of length 127Mbit/s, 19.05 Mchips/s
Stream2: 2-MSK, modulation index 0.5

COM-8004: 07 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01
COM-1002: 08 D7 03 00 00 00 FF 00 87 10 00
COM-1001: 84 EB 01 00 00 00 02 99 00
COM-1019: 9F F5 3C 7F 00 00 02 41 00 00 00 00 00 00 00 00 FF 00 87 1C 01
COM-1018: 9F F5 3C 7F 00 00 02 41 00 00 00 00 00 00 00 00 82 85 81
COM-1028: C2 F5 00 00 00 00 FF 80 00 00 83 02
COM-1027: C2 F5 00 00 00 00 00 02 94 02
COM-8003: 07 04 00 20 00 00 00 00 00 00 00 00 28
COM-1005: 2C