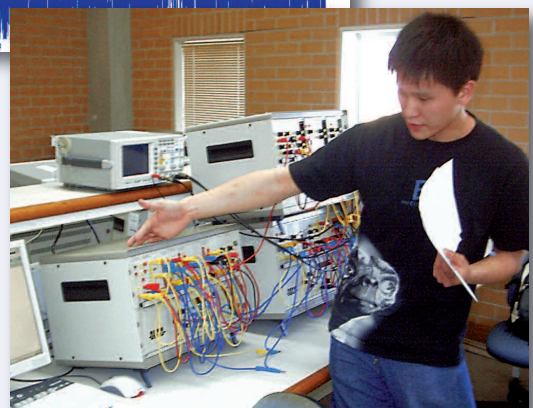
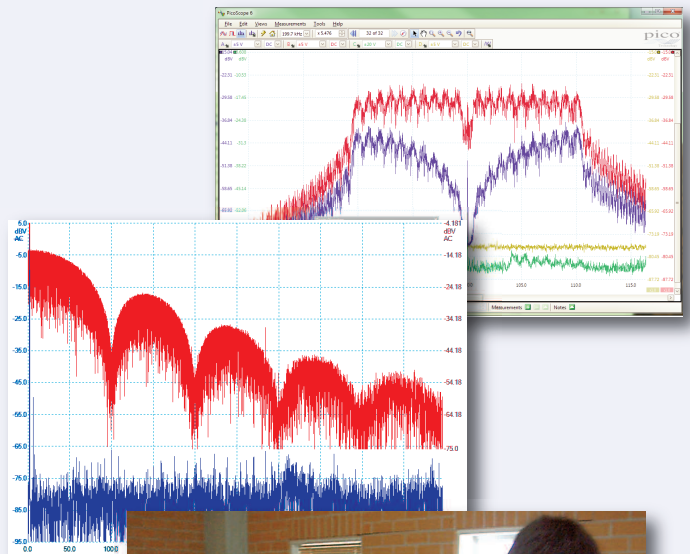


UPDATED

Exploring Wireless Communications Standards with Emona TIMS

Telecommunications, SDR and Signals & Systems Hands-on Lab Experiments for University and College Students

LTE
TETRA
Wideband-CDMA
HSDPA
CDMA2000®
EDGE
cdmaOne (IS-95)
GSM
Wi-Fi
WiMAX
Cordless Telephone
ZigBee™
DECT
Bluetooth®
Near Field Communications
UWB
RFID
Digital Radio DAB
DVB-S
Satellite Modems
Satellite Links
EBEM
Deep Space Telemetry
GPS
and much more . . .



Exploring Wireless Communications Standards with Emona TIMS

TIMS is used by students to implement modulation and coding schemes at the block diagram level. These schemes are **modelled** often partially and not implemented fully or at commercial RF frequencies. All measurements obtained with TIMS are mathematically correct and correspond to theory. Note that with TIMS, expensive commercial RF test instruments are **not** required.

APPLICATION	MODULATION SCHEME	TIMS EXPERIMENTS
REMOTE CONTROL APPLICATIONS		
ZigBee™	BPSK	L-28, L-29, L-50, L-118; D1-08, D7-03
	also O-QPSK	D4-05, D4-06
Remote Keyless Entry	BFSK	D7-01, D7-02, L-32, L-33
Tire Pressure Monitoring System	OOK	L-26, L-27
CORDLESS RADIOTELEPHONE		
Cordless Telephone	FM	L-12, L-13, L-14, L-84, L-85
Personal Handy System	pi/4 DQPSK	D4-06
Digital European Cordless Telephone (DECT)	MSK, GFSK	D4-04, D4-06
CELLULAR TELEPHONE		
GSM / GPRS	MSK	D4-04, D4-06
	also BFSK	L-32, L-33; D1-07, D7-02
EDGE	8-PSK	L-115, L-34
Wideband-CDMA	QPSK: DS-SS	L-62 to L-65, L-67; D5-01, D6-02, L-30, L-31
HSDPA	QPSK, QAM, 16QAM: CDMA	L-48, L-49
HSUPA	QPSK, QAM: CDMA	L-48, L-49, L-30, L-31, L-62 to L-65, L-67
CDMA2000®	CDMA	D5-01, D6-01, L-62 to L-65, L-67
	with QPSK or OQPSK	D2-13, L-30, L-31, D4-05, D4-06
Long Term Evolution (LTE)	OFDM	D3-06, L-103, D8-03, L-151 to 156
	with QPSK, 16QAM	D2-13, L-30, L-31, L-115
cdmaOne (IS-95)	O-QPSK: CDMA	D4-05, D4-06
EV-DO	QAM: CDMA	L-48, L-49, L-62 to L-65, L-67
TETRA	pi/4-DQPSK, QAM, 16QAM	D4-06, L-48, L-49, L-115
WIRELESS DATA		
IEEE 802.11 Wireless LAN	DBPSK: DS-SS	D6-01, D6-02, L-57, D7-03
	also GFSK: FH-SS	D3-09 to D3-12, D5-02, D3-18, D7-03
Wi-Fi 1 (802.11b)	QPSK: DS-SS	L-30, L-31, L-115, L-62 to L-65, D5-01, D6-01
Wi-Fi 2 (802.11a/g)	OFDM/DS-SS with	D3-06, L-103, L-48, L-49, D5-01, D8-03
	BPSK, QPSK, 16QAM	L-30, L-31, L-28, L-29, L-115
WiMAX	OFDM	D3-06, L-103; D8-03, L-151 to 156
	with BPSK, QPSK, QAM, 16QAM	L-30, L-31, L-28, L-29



APPLICATION	MODULATION SCHEME	TIMS EXPERIMENTS
PERSONAL AREA NETWORK		
Bluetooth® 1.0	BFSK	D7-01, D7-02, L-32, L-33
	also FH-SS with GFSK	D3-09 (FH-SS), D3-18 (GFSK)
Bluetooth® 2.0 - Enhanced Data Rate	pi/4-DQPSK	D4-06
Near Field Communication (NFC)	ASK (Manchester)	L-26, L-27, L-42 (line codes); D1-06
RFID	PWM, FSK, ASK, BPSK	D1-06, D1-07, D1-08, L-28, L-29, L-27, L-26
	also AM, FM	A1-04, A2-09, A2-10, A2-11 to 15, D2-11
UWB	PAM, OOK, PSM (MHP, gaussian), BPSK/QPSK	D4-08, D4-12, D4-13, D4-15 A1-11, D1-08
DIGITAL COMMERCIAL BROADCASTING		
Digital Radio DAB	OFDM with DQPSK	D3-06; L-103, D4-06, D8-03, L-151 to 156
Digital Video Broadcasting-Satellite (DVB-S)	QPSK, 16QAM	L-30, L-31, L-115, L48, L-49
Digital Video Broadcasting-Satellite (DVB-S2)	QPSK, 8PSK	L-30, L-31, L-115, L-34
Digital Video Broadcasting-Terrestrial (DVB-T)	OFDM with QPSK, 16QAM	D3-06, L-30, L-31; L-115, L-151 to 156
SATELLITE COMMUNICATIONS		
Satellite Modems	BPSK, QPSK, OQPSK, 8PSK, 16QAM	L-28/29, L-50, L-118; D4-03 to D4-06 L-115
	also Convolutional Coding	L-86, L-87; D2-09
Satellite Links	QPSK, pi/4-QPSK, MSK	L-28/29, D4-04, D4-06, L-31, L-31
with a combination of any of the following:	TCM Trellis Coding	L-59, L-61; D2-10
	PCM	D1-11, D1-12; L-24, L-25
	Delta Mod/Adaptive Delta Mod	L-43 to 46; D1-13 to 15
	FDM	L-17, A2-07
	CDMA	L-62, L-64, L-65; D6-01
	TDMA	D5-03 (TH-SS); A1-11 (PAM & TDM)
Enhanced Bandwidth Efficient Modem (EBEM)	8PSK	L-115, L-34
Deep Space Telemetry	BPSK	L-28, L-29, L-50, L-118; D1-08, D4-03
NAVIGATION		
GPS	BPSK	L-28, L-29, L-50, L-118; D1-08, D4-03

KEY

L-xxx : TIMS LabSheet Experiment number. LabSheet experiments are concise 2 page experiment descriptions.
Dx-xx : TIMS Student Text Volume (Dx) and Experiment number (-xx). Student text are detailed experiments.

NOTES

The information in this document is provided as an overview and summary of the typical modulation and coding schemes implemented. Actual data as well as information regarding current standards may differ from the statements contained in the above. Error and Omissions Excepted.



Emona TIMS Experiments Listing

Below is a listing of the contents pages of the 11 volumes of TIMS detailed "Student Text" Experiment Manuals, the TIMS Signals & Systems Lab Manual and the unique TIMS "LabSheet" Experiments Manual.

New TIMS experiments are published regularly. All professors using TIMS have free web access to all TIMS experiment documents including the latest experiments and latest user manual chapters.

Emona TIMS Student Text Lab Manual Volume A1 - Fundamental Analog Experiments

186 pages

Introduction to modelling with TIMS.	A1-01
Modelling an equation	A1-02
DSBSC generation	A1-03
Amplitude modulation	A1-04
Envelopes	A1-05
Envelope recovery	A1-06
SSB generation - the phasing method	A1-07
Product demodulation - synch. & asynch	A1-08
SSB demodulation - the phasing method	A1-09
The sampling theorem.	A1-10
PAM & time division multiplex	A1-11
Power measurements.	A1-12
Appendix A - Filter responses	A1
Appendix B - Some Useful Expansions	B1

Emona TIMS Student Text Lab Manual Volume D1 - Fundamental Digital Experiments

178 pages

PRBS generation.	D1-01
Eye patterns	D1-02
The noisy channel model	D1-03
Detection with the DECISION MAKER	D1-04
Line coding	D1-05
ASK - amplitude shift keying	D1-06
FSK - frequency shift keying	D1-07
BPSK - binary phase shift keying	D1-08
Signal constellations.	D1-09
Sampling with SAMPLE & HOLD.	D1-10
PCM encoding	D1-11
PCM decoding	D1-12
Delta modulation.	D1-13
Delta demodulation.	D1-14
Adaptive delta modulation	D1-15
Delta-sigma modulation	D1-16
FSK - asynchronous single branch detection	D1-17

Emona TIMS Student Text Lab Manual Volume A2 - Further & Advanced Analog Expts

172 pages

Amplitude modulation - method 2	A2-01
Weaver's SSB generator	A2-02
Weaver's demodulator	A2-03
Carrier acquisition and the PLL	A2-04
Spectrum analysis - the WAVE ANALYSER	A2-05
Amplifier overload	A2-06
Frequency division multiplex	A2-07
Phase division multiplex	A2-08
Analysis of the FM spectrum.	A2-09
Introduction to FM using a VCO	A2-10
FM and the synchronous demodulator	A2-11
Armstrong's phase modulator.	A2-12
FM deviation multiplication	A2-13
FM and Bessel zeros	A2-14
FM demodulation with the PLL	A2-15
The Costas loop	A2-16
Appendix A - Tables of Bessel Coefficients	A2-A

Emona TIMS Student Text Lab Manual Volume D2 - Further & Advanced Digital Experiments

162 pages

BER measurement in the noisy channel	D2-01
BER instrumentation macro model	D2-02
Bit clock regeneration	D2-03
Carrier acquisition.	D2-04
DPSK - carrier acquisition and BER	D2-05
PCM TDM	D2-06
Block coding & decoding.	D2-07
Block coding and coding gain.	D2-08
Convolutional coding	D2-09
TCM - trellis coding.	D2-10
PPM and PWM.	D2-11
QAM and 4-PSK.	D2-12
Multi-level QAM & PSK	D2-13
Spread spectrum - DSSS and CDMA	D2-14
Digital utility sub-systems	D2-15

Emona TIMS Student Text Lab Manual Volume D3 - Advanced Digital Experiments

168 pages

ISI: PAM & ASK over band-limited channels	D3-01
Equalization for ISI	D3-02
Pulse shaping for bandlimited channels	D3-03
Base-line wander and line coding	D3-04
Timing jitter in band-limited channels	D3-05
Introduction to OFDM principles (expanded, V3)	D3-06
Additive noise in digital baseband channel	D3-07
Additive noise in block coded channel	D3-08
Introduction to FHSS using FSK	D3-09
FHSS: fast and slow hopping	D3-10
FHSS and bit error rate performance	D3-11
FHSS: hop pattern diversity correlation	D3-12
The SONET PCM data frame	D3-13
SONET STS-1 demultiplexing	D3-14
SONET STS-1 transmission via an optical link with bit clock recovery.	D3-15
SONET STS-3 multiplexing.	D3-16
Bit Error Rates (BER) in simple digital channels	D3-17
GFSK - Gaussian frequency shift keying	D3-18

Emona TIMS Student Text Lab Manual Volume D4 – Further Advanced Digital Experiments

452 pages

BER EXPERIMENT SERIES –	
BER measurement of unipolar NRZ signals in a baseband distortionless channel	D4-01
BER measurements of bipolar NRZ signals in a baseband distortionless channel	D4-02
BER measurement of coherent BPSK signalling in an ideal distortionless channel	D4-03
MSK MODULE SERIES	
MSK in a passband channel, with BER vs SNR	D4-04
OQPSK in a passband channel, with BER vs SNR	D4-05
PI/4-DQPSK, PI/4-QPSK, OQPSK & MSK: spectra and constellations.	D4-06
UWB MODULES SERIES -	
Introduction to UWB pulse shapes and spectra	D4-08
UWB modulation & detection: OOK, PPM, BPM & OPM	D4-09
Multiple-access UWB using orthogonal pulse modulation with modified hermite pulses (MHP)	D4-10
Multi-band UWB modulation (DRAFT)	D4-11
UWB – detailed experiments in UWB communications systems	D4-12
UWB – multiple access techniques :	
TDMA, DS-CDMA,OPM-MA	D4-13
UWB – BER using BPM and OOK signalling	D4-14
UWB – Processing Gain and UWB operating below the noise level.	D4-15
UWB –Bandpass system	D4-16

Emona TIMS Student Text Lab Manual Volume D5 – Basic Spread Spectrum Experiments

168 pages

SPREAD SPECTRUM EXPERIMENT SERIES –	
Spread Spectrum - Analysis of Direct Sequence Spread Spectrum	D5-01
Spread Spectrum - Analysis of Frequency Hop Spread Spectrum	D5-02
Spread Spectrum - Analysis of Time Hop Spread Spectrum	D5-03
Spread Spectrum - Analysis of Hybrid FH-DS Spread Spectrum.	D5-04

Emona TIMS Student Text Lab Manual Volume D6 – Advanced Spread Spectrum Experiments

168 pages

SPREAD SPECTRUM EXPERIMENT SERIES –	
DS-CDMA/BPSK- 3 Channel Basic System	D6-01
DS-SS Baseband System- Processing Gain Measure	D6-02
FH-CDMA/BFSK.	D6-03

Emona TIMS Student Text Lab Manual Volume D7 – Advanced BER Experiments

154 pages

Non coherent BFSK-BER measurement	D7-01
Coherent BFSK-BER measurement	D7-02
DBPSK-BER measurement	D7-03
Coherent QPSK-BER measurement	D7-04

► **NEW:**

Emona TIMS Student Text Lab Manual Volume D8 – Multipath and OFDM Experiments

102 pages

Time-invariant fading channel characteristics	D8-01
ISI rejection in DS SS	D8-02
OFDM in bandlimited, multipath, time-invariant channel with BER measurement *	D8-03

► **NEW:**

Emona TIMS Student Text Lab Manual Volume D9 – RADAR Signals Experiments

66 pages

RADAR signals	
Constant-frequency pulse	
Linear-frequency pulse	
Coherent train of identical unmodulated pulses	
Coherent train of identical linear-FM pulses	
Phase-coded pulse	
Stepped-frequency pulse	D9-01

Emona TIMS Experiments Listing - continued

Emona TIMS Student Text Lab Manual

TIMS Signals & Systems-V1 Experiments

(The S&S V1 experiments utilize the manually controlled LAPLACE-V1 and z-TRANSFORM-V1 plug-in modules.)

192 pages

Introduction	
Special signals – characteristics and applications . . .	S1-01
Modeling linear and nonlinear systems with TIMS . . .	S1-02
Unraveling convolution	S1-03
Comparing responses in the time and frequ domains	S1-04
A Fourier series analyzer	S1-05
Spectrum analysis of various signal types	S1-06
Getting started with poles and zeros in the Laplace domain	S1-07
Sampling and Aliasing	S1-08
Getting started with analog-digital conversion	S1-09
Discrete-time filters – Finite Impulse Response	S1-10
Using poles and zeros in the z plane: discrete-time filters	S1-11
Discrete-time filters – practical applications.	S1-12
Parseval’s Theorem- Relationship between time & frequency domain	S1-13
Random Signal Analysis: AWGN and erfc	S1-14

► **NEW:**

Emona TIMS Student Text Lab Manual

TIMS Signals & Systems-V2 Experiments

(The S&S V2 experiments utilize the PC controlled LAPLACE-V2, z-TRANSFORM-V2, TRIPLE ADDER-V2 and PC-MODULES CONTROLLER plug-in module set.)

210 pages

Introduction	
Introduction to the Signals & Systems V2 module set . . .	S2-01
Special signals – characteristics and applications . . .	S2-02
Systems: linear and nonlinear	S2-03
Unraveling convolution	S2-04
Integration, correlation & matched filters	S2-05
Exploring complex numbers and exponentials	S2-06
Build a Fourier series analyzer	S2-07
Spectrum analysis of various signal types	S2-08
Poles and zeros in the Laplace domain	S2-09
Sampling and Aliasing	S2-10
Getting started with analog-digital conversion	S2-11
Discrete-time structures – Finite Impulse Response . . .	S2-12
Poles and zeros in the z plane with IIR systems	S2-13

► **EXPANDED:**

Emona TIMS LabSheet Experiments

394 pages

Emona TIMS LabSheets are concise, 2 page, quick-start experiment guides

Introduction to TIMS	L-01
Modelling equations	L-02
DSB - generation.	L-03
Product demodulation	L-04
Amplitude modulation - 1.	L-05

Amplitude modulation - 2.	L-06
Envelope detection	L-07
SSB generation.	L-08
SSB demodulation.	L-09
ISB - independent sideband	L-10
Armstrongs phase modulator	L-11
FM generation by VCO	L-12
FM demodulation by PLL	L-13
FM demodulation by ZX counter	L-14
Sampling.	L-15
PAM & TDM.	L-16
FDM - frequency division multiplex	L-17
Phase division multiplex - generation	L-18
Phase division multiplex - demodulation	L-19
PWM - pulse width modulation	L-20
Carrier acquisition - PLL	L-21
Spectra using a WAVE ANALYSER	L-22
Complex analog messages	L-23
PCM encoding	L-24
PCM decoding	L-25
ASK generation	L-26
ASK demodulation	L-27
BPSK modulation	L-28
BPSK demodulation.	L-29
QPSK generation	L-30
QPSK demodulation	L-31
FSK generation.	L-32
FSK envelope demodulation	L-33
Constellations.	L-34
DSSS spread spectrum.	L-35
Eye patterns.	L-36
PRBS messages.	L-37
Detection with the DECISION MAKER	L-38
The noisy channel.	L-39
BER instrumentation.	L-40
BER measurement introduction	L-41
Line coding & decoding.	L-42
Delta modulation	L-43
Delta-sigma modulation	L-44
Adaptive delta modulation	L-45
Delta demodulation.	L-46
Bit clock regeneration	L-47
QAM generation	L-48
QAM demodulation	L-49
BPSK.	L-50
Broadcasting	L-51
Fibre optic transmission	L-52
Multi channel FDM digital fibre link.	L-53
PCM-TDM-T1 implementation	L-54
DPSK & BER.	L-55
Bit clock regen in a PCM-TDM system	L-56
DPSK and carrier acquisition	L-57
Intro to DSP - A & D implementation compared.	L-58
TCM - trellis coding.	L-59
Matched filter detection	L-60

TCM coding gain	L-61	UWB - BER measurement of OOK signalling	L-122
CDMA introduction	L-62	UWB - Multiple Access Techniques - DS CDMA	L-123
CDMA processing gain	L-63	UWB - Multiple Access Techniques - OPM.	L-124
CDMA - 2 channel	L-64	UWB - Multiple Access Techniques - TDMA	L-125
CDMA - multichannel	L-65	UWB - Observation in frequency domain	L-126
Unknown signals - 1	L-66	UWB - operating bellow noise level	L-127
CDMA at carrier frequencies	L-67	UWB - processing gain measurement	L-128
Non-linearity & distortion	L-68	UWB - UWB employing BPM	L-129
PPM pulse position modulation	L-69	UWB - UWB employing OOK	L-130
Speech in telecommunications	L-70	UWB - UWB employing OPM	L-131
Binary data via voiceband	L-71	UWB - UWB employing PPM.	L-132
Multilevel data via voiceband	L-72	UWB -Observation in time domain	L-133
Data rates & voiceband modems - transmission	L-73	UWB -bandpass system	L-134
Data rates & voiceband modems - demodulation	L-74	Spread Spectrum - analysis of THSS	L-135
System fault finding	L-76	Spread Spectrum - analysis of FHSS-SFH	L-136
Frequency synthesis with the PLL	L-77	Spread Spectrum - analysis of hybrid FH-DS SS	L-137
Block code encoding (method 1).	L-78	Spread Spectrum - analysis of hybrid FH-DS SS	L-138
Block code encoding (method 2).	L-79	Spread Spectrum - analysis of FH-SS	L-139
Block code decoding	L-80	Spread Spectrum - analysis of DSSS	L-140
Error correcting with block coding	L-81	DSSS baseband system-processing gain measurement- Broadband jamming	L-141
Superheterodyne	L-82	DSSS baseband system-processing gain measurement- Pulse jamming	L-142
Customizable digital sequences	L-83	DSSS baseband system-processing gain measurement- Demonstration of LPD Signals	L-143
FM deviation multiplication	L-84	► THE LATEST ADDITIONS:	
FM and Bessel zeros	L-85	BER measurement of coherent BFSK signalling in an ideal distortionless channel	L-144
Convolutional coding - I	L-86	BER measurement of non-coherent BFSK signalling in an ideal distortionless channel.	L-145
Convolutional coding - II	L-87	BER measurement of coherent detection of DBPSK signalling in an ideal distortionless channel.	L-146
Optical signal splitting & combining	L-88	BER measurement of non-coherent detection of DBPSK signalling in an ideal distortionless channel.	L-147
Fibre optic bi-directional communication	L-89	CDMA-FHSS 3 Channel basic system.	L-148
WDM – wave division multiplex	L-90	Time-invariant fading channel.	L-149
The SONET PCM Data Frame	L-92	ISI rejection in DS SS systems.	L-150
SONET STS-1 demultiplexing	L-93	IDFT, Complex Exponent & Complex Quad Signals.	L-151
SONET Transmission via an optical link	L-94	OFDM, Cyclic Prefix & PAPR.	L-152
SONET STS-3 multiplexing	L-95	OFDM & Channel Equalisation with BER Measurement	L-153
SONET STS-3 demultiplexing	L-97	OFDM in band limited, multipath, time-invariant channel with BER measurements	L-154
Intro to FHSS using FSK	L-98	Comparing QAM to OFDM in a multipath channel	L-155
FHSS Slow and Fast Hopping	L-99	Multipath effects on OFDM cyclic prefix with BER Measurements	L-156
FHSS and BER performance	L-100	Radar signals: constant-frequency pulse.	L-157
Multi channel FHSS with BER.	L-101	Radar signals: linear-frequency modulated pulse.	L-158
Hybrid DSSS FHSS system	L-102	Radar signals: coherent train of LFM pulses.	L-159
Introduction to OFDM generation.	L-103	Radar signals: phase-coded pulse.	L-160
Introductory PAM-TDM	L-104	Radar signals: coherent train of identical unmodulated pulses.	L-161
Introduction to QASK	L-105	Radar signals: stepped-frequency pulse.	L-162
Introduction to pulse shaping.	L-106	BER of Coherent QPSK in distortionless channel.	L-163
Noise generation using binary sequences.	L-107	PLL and Costas Loop in carrier regeneration.	L-164
Principles of spread spectrum	L-108		
SSB linear amplifier measurements.	L-112		
SNR - SSB compared with DSBSC	L-113		
AM demodulation and SNR	L-114		
4/8/16-QPSK and 4/8/16-QAM with BER in a noisy channel	L-115		
BER baseband BPNRZ signalling	L-116		
BER baseband UNRZ signalling.	L-117		
BER coherent BPSK signalling	L-118		
Parseval's Theorem	L-119		
Random Variable Analysis_AWGN_erc	L-120		
UWB - BER measurement of BPM signalling.	L-121		

HOW STUDENTS FOLLOW THEORY TO BUILD TIMS COMMUNICATIONS EXPERIMENTS

Students use exactly the same approach to building telecommunications experiments in both Emona TIMS hardware and Emona TutorTIMS pre-lab learning software.

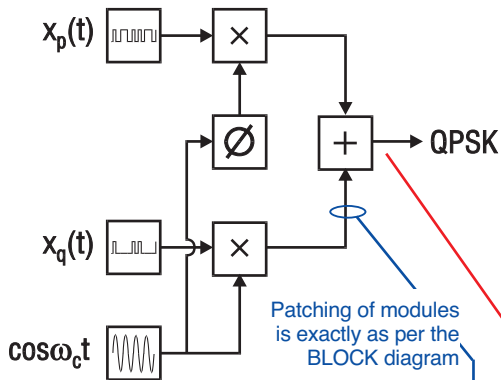
START WITH MATH OR THEORY

$$x_p(t) \cdot \cos \omega_c t + x_q(t) \cdot \sin \omega_c t = \text{QPSK}$$

where $x_p(t)$ and $x_q(t)$ are alternate elements of a digital sequence.

Telecommunications text books are a source of equations and theories. This is the starting point for a TIMS & TutorTIMS experiment.

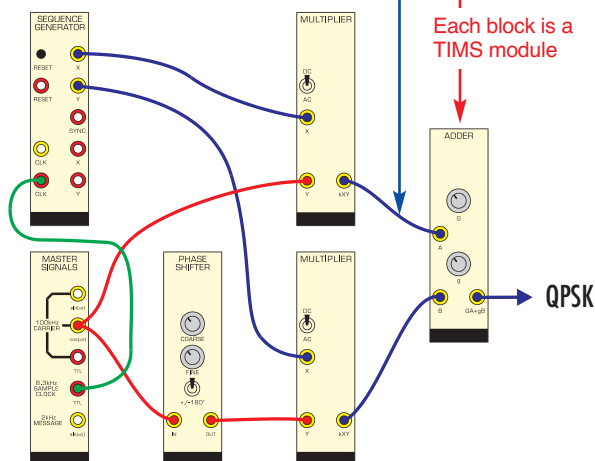
REPRESENT IT AS A BLOCK DIAGRAM



In telecommunications, Math and Theory is always expressed in the universal language of BLOCK DIAGRAMS.

Telecommunications engineers make sense of math and theory through BLOCK DIAGRAMS.

BUILD IT USING TIMS & TutorTIMS MODULES



TIMS & TutorTIMS both realise telecommunications BLOCK DIAGRAMS. TIMS realises block diagrams with real circuits. TutorTIMS realises block diagrams with on-screen graphical blocks, which run simulation code in the background.

References

A non-exhaustive list of sources includes: Digital Communications, Kamillo Feher; Digital Communications with Fiber Optics & Satellite Applications, Harold B. Killen; Practical Digital Wireless Signals, Earl McCune. IEEE, industry Fora and Alliances. All registered trademarks, including ZigBee™, CDMA2000™, Bluetooth™ and others are acknowledged as the property of their registered owners.

Available from:

Emona Instruments Pty Ltd

78 Parramatta Road

Camperdown NSW 2050 AUSTRALIA

Tel: +61-2-9519-3933 Fax: +61-2-9550-1378

URL: www.tims.com.au

Email: sales@tims.com.au