DIGITAL MOBILE RADIO ASSOCIATION

Underperformance of digital PMR systems – commonly overlooked implementation issues and solutions.

Tom Johnson,
Chair, Technical Working Group, DMR Association

PMRExpo
PROFESSIONELLER MOBILFUNK UND LEITSTELLEN

The DMR Association

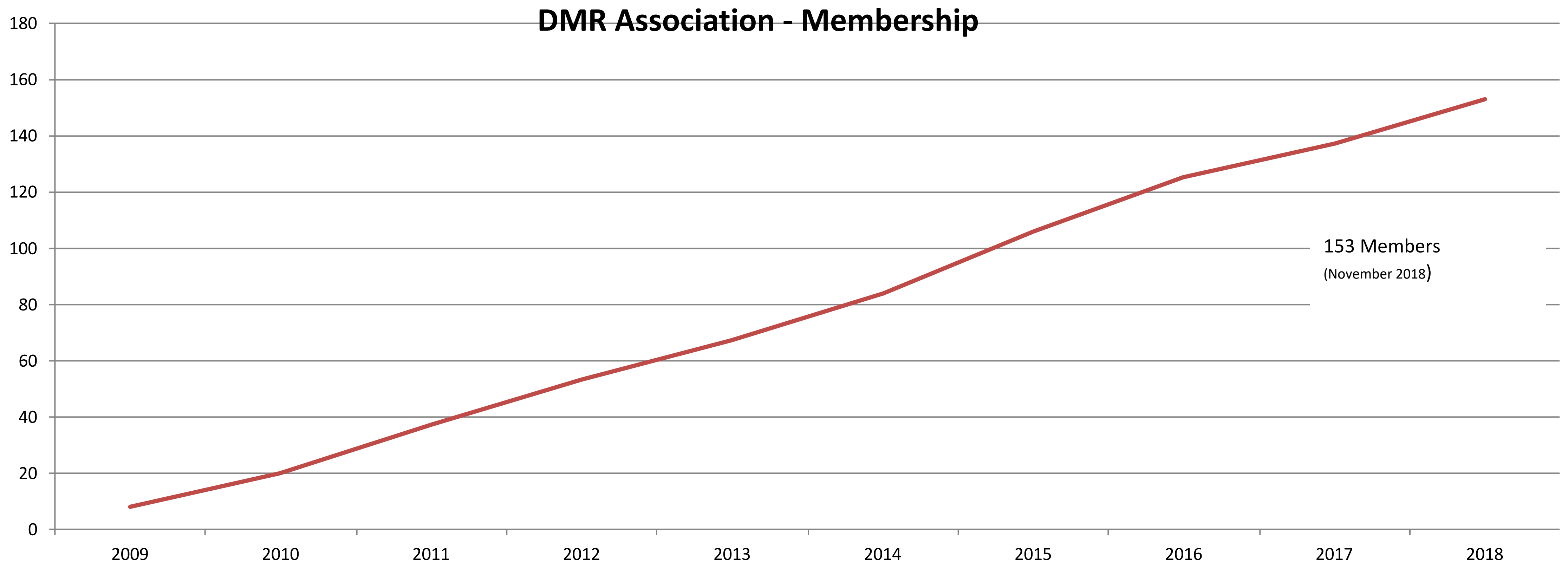
- Industry body representing the DMR market.

- Established in 2005 as the DMR-MOU Association to support ETSI during the DMR standardisation process our membership is open to any organisation or individual interested in using or building DMR products or in supporting the DMR standard in other ways. We’re in frequent and direct dialogue with regulators, trade bodies and standards organisations around the world to maintain the DMR standard both for our members and for all other users.

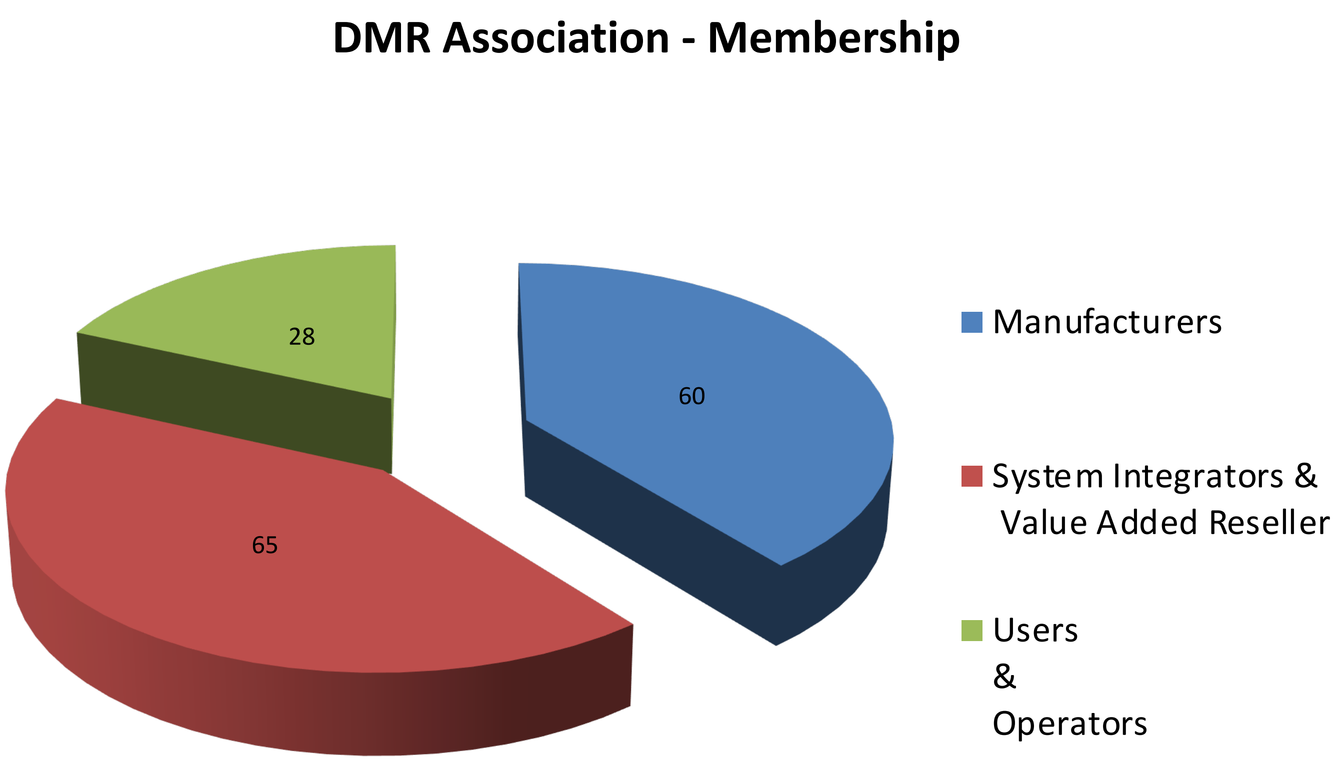
Mission and Objectives

- For DMR we will:
  - support the growth of the market
  - create and maintain an interoperability testing and certification program
  - offer education, promotion and discussion about the standard
  - work with regulators to develop an environment in which the technology can flourish

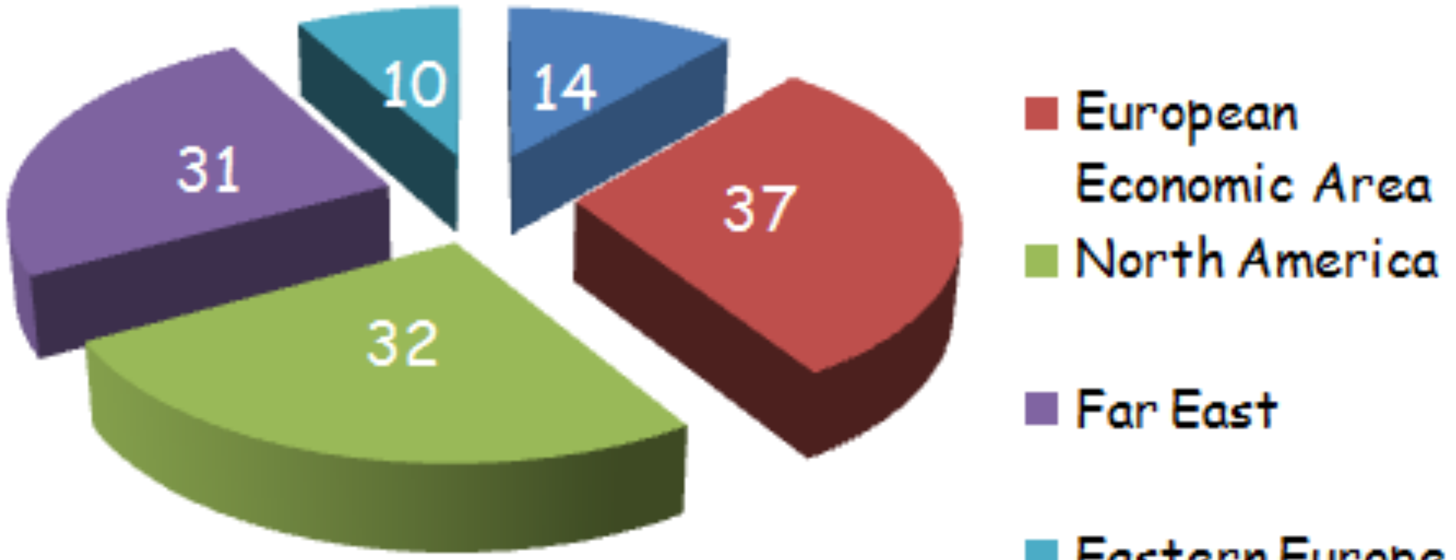
Membership Year by Year



Membership By Category



Membership By Region



ETSI World Class Standards
MOTOROLA
TRBOnet Digital Technologies
neocom software
CML Microcircuits COMMUNICATION SEMICONDUCTORS
3G 三吉电子
Anritsu Discover What's Possible
Uni.
Samhoo
Hytera Respond & Achieve
sepura
aselsan
LEONARDO
AVTEC
Omsk Manufacturing Association named after A.S. Popov
Ponti Radio soluzioni senza fili PR
TrafficLink
HARRIS
Anritsu
HQT
RADIODATA
东信 EASTCOM
SmartPTT
TWISTEDPAIR
NT 新吉信 New Technology
Kydera
RADIODATA
ZETRON
BFDX
RadioActivity Infinite Solutions
euromicron telent service • commitment • value
KIRISUN
PUXING
Wintec wireless electronics
simoco
SCHNOOR Industrieelektronik • Nachrichtentechnik • Systemtechnik
tait communications
euromicron telent
WIRELESS CORPORATION
VictelGlobal
JVCKENWOOD
omnitronics Challenging Communication Boundaries
XWORKS
MIDLAND
3G 三吉电子
SmartPTT
emc www.emc-spa.com
AEROFLEX
福建联拓科技有限公司 LINKTOP TECHNOLOGIES (FUJIAN) CO., LTD. LINKTOP Technologies Website Link
TRBOnet Digital Technologies
SIP PARTNERS
catalyst communications technologies
LARIMART a LEONARDO company
PRESCOM
安信卓 EXCERA
TELEX Radio Dispatch
neocom software
etherstack
fjord-e-design mobile communication engineering
DRC Solutions Inspired
Vertex Standard
SICOMM
Lisheng
ZTE高达
E I L Company Limited an expert in bridging the electronic component

Tom Johnson : Introduction

- Ex Chief Engineer: Fylde Micro Ltd
- Network designer and hardware/software developer.
- Contracted to DMR Association part time as Chair of the Technical Working Group (TWG)

Technical Working Group (TWG)

- TWG meets every 6 weeks approximately
- Considers matters relating to
  - DMR Standards
  - Interoperability (IOP)
  - DMRA Standards (Encryption/AIS etc)
  - Conformance and compliance.
- Direct input to ETSI (TGDMR).
  - ETSI<>DMRA MoU in place agreed June 2018

DMR Overview

- Low cost, low complexity, open standard
- Higher traffic capacity & spectral efficiency
  - 2 for 1,
  - half the equipment.
- Access to digital features for improved functionality, voice quality & security
- Smooth migration from analogue with existing spectrum & licensing
- Longer battery duration
- Conventional, Trunking, Simulcast

ETSI DMR Standard Parts

DMR Tier I: Unlicensed

- Products for license-free use in the 446 MHz band.

DMR Tier II: Conventional

- Licensed conventional radio systems operating in LMR frequency bands 30 to 1000 MHz. Targeted at users who need spectral efficiency, advanced voice features and integrated IP data services in licensed bands.

DMR Tier III: Trunked

- Trunking operation in frequency bands 30 to 1000 MHz. The ETSI Tier III standard supports voice and short messaging handling similar to MPT1327.

ETSI DMR Standards

- The current version of ETSI standards as of September 2018 are:
  - ETSI TS 102 361-1 DMR Air Interface Protocol (V2.5.1)
  - ETSI TS 102 361-2 DMR Voice and Generic Services (V2.4.1)
  - ETSI TS 102 361-3 DMR Data Protocol (V1.3.1)
  - ETSI TS 102 361-4 DMR Trunking Protocol (V1.9.2)
  - ETSI TR 102 398 DMR General System Design (V1.3.1)

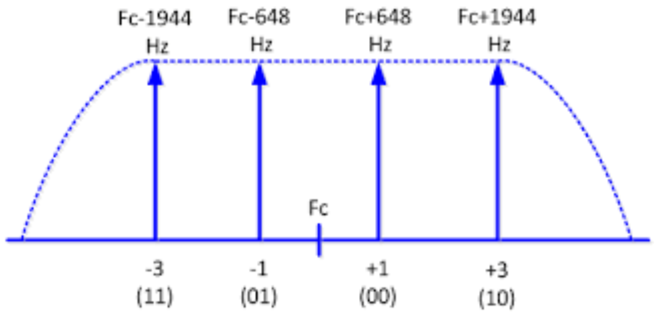
Can be freely downloaded from the ETSI or DMR Association websites

Recent Developments

- ETSI 102 361-4 V1.8.1 (Tier 3)
  - introduced a powerful new set of group related features
    - Talkgroup Subscription
    - Talkgroup Attachment
- ETS 102 361-4 V1.9.1 (Tier 3)
  - 3 major function additions
    - TSCCAS (Alternate control channel)
    - Unified Single Block Data Polling Service
    - Channel authorization

DMR Performance

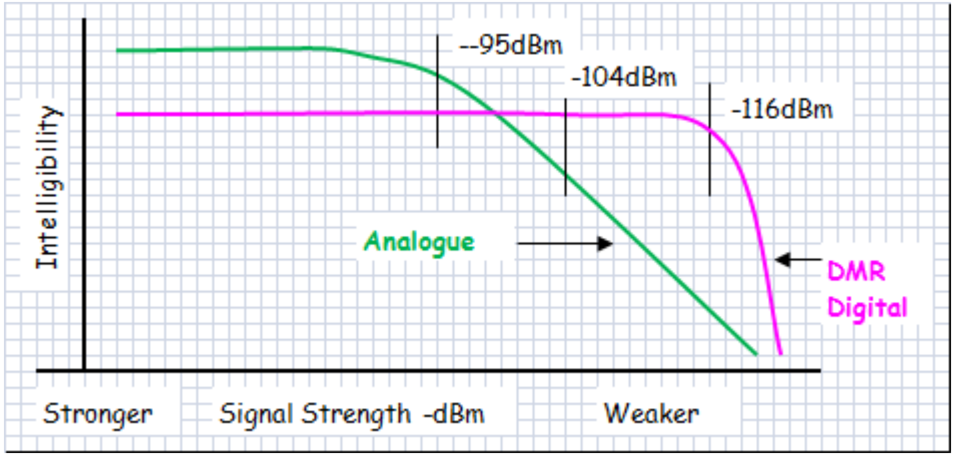
- Fundamentals
  - 9600 baud 4 Level FSK
  - 4800 symbols per second



- Special filters ensure modulation complies with transmission mask as specified ETS EN 300 113 (Root Raised Cosine Filter) allowing DMR systems to co-exist in existing 12.5kHz assigned channels (no exclusive frequencies required)

Performance

- In theory performance (range) should be better than equivalent analogue transmission (with same RF power etc).



- In practice
  – Some say it is
  – Some say it isn't
  – For those that say it isn't, lets have a look at some of the possible reasons:

Performance

- Noise Floor.
  - The issues for the digital systems is carrier to noise (C/N). The (C/N) performance for DMR is 10 to 12dB. This means that the signal level must be 10 to 12 dB higher than the noise to successfully retrieve the data (voice). Interference also manifests itself similar to noise so C/N can also be C/I. In contrast an analog system is able to tolerate a signal/noise (S/N) of 6 to 7dB (FM capture effect in the demodulator).

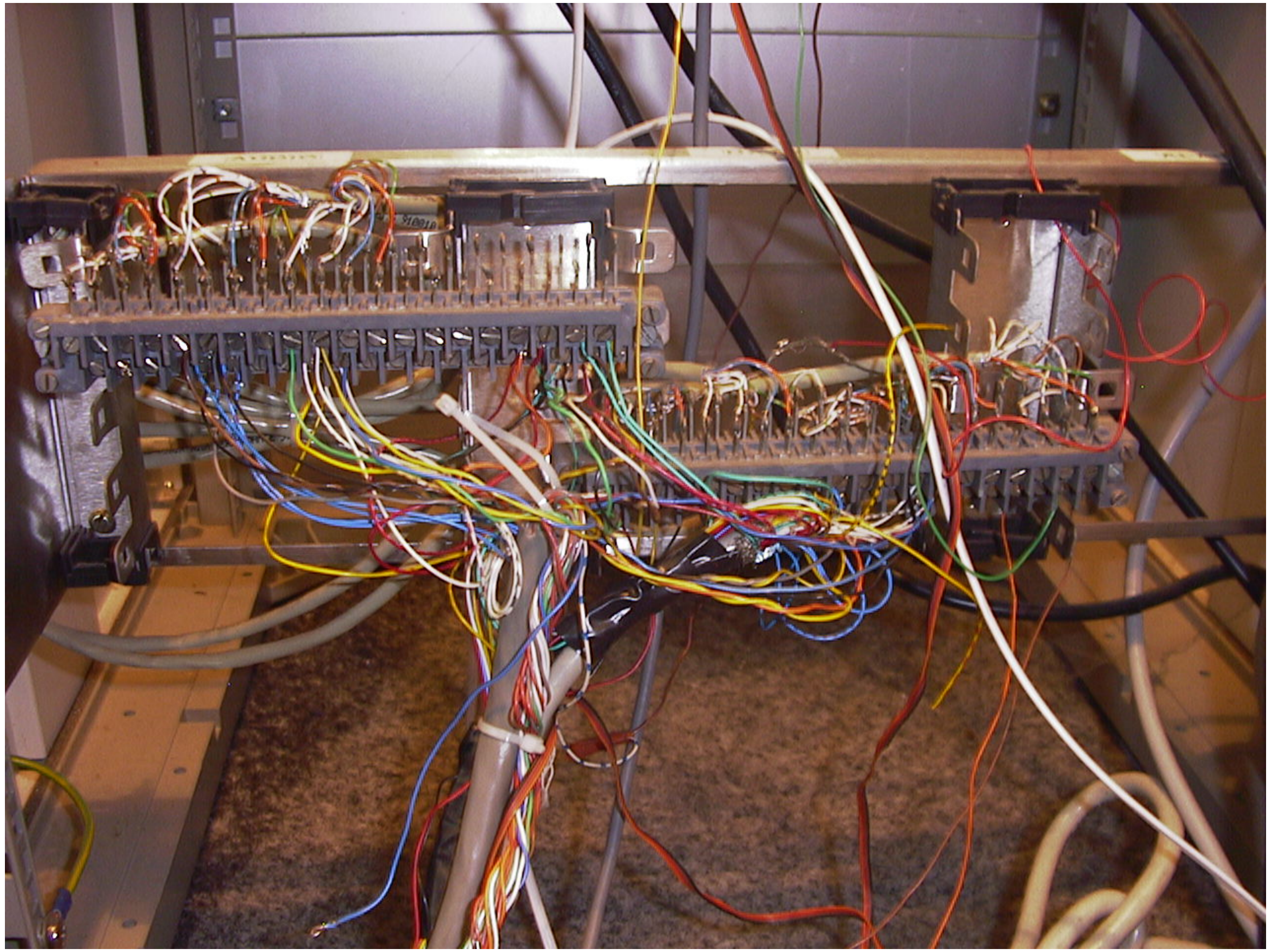
Noise Floor Mitigation

- Whether the signal is analogue or digital the signal/noise (or interference) must be better than a certain value to provide an acceptable grade of service.
- If the transmission is analogue the noise will be heard above the voice.
- If the transmission is digital if the carrier/noise is not high enough nothing will be heard at all.
- IF THE NOISE FLOOR AT THE RECEIVER ANTENNA IS HIGH, THIS NOISE ADDS TO THE NOISE FLOOR OF THE RECEIVER.
- This means that the added receiver sensitivity can only be realised if the received signal is 10dB to 12dB higher than the noise (or interference).
  - For example a signal at -112dBm will only be successfully received if the noise floor is better than -122dBm.

Noise Floor Mitigation

- Digital does not fix poor Radio Site Engineering.
- Digital does not fix a high noise floor
  - Inappropriate choice of radio site
  - Proximity of receiver antenna to other transmitter antennas (wide band and spread spectrum 3G/4G LTE etc)
  - Incorrect or badly positioned antenna
  - Poorly designed or adjusted antenna duplexer/combiner
  - External interference (LED Floodlights !!)
  - Poor Grounding, cable screening etc

Example Photos



Example Photos

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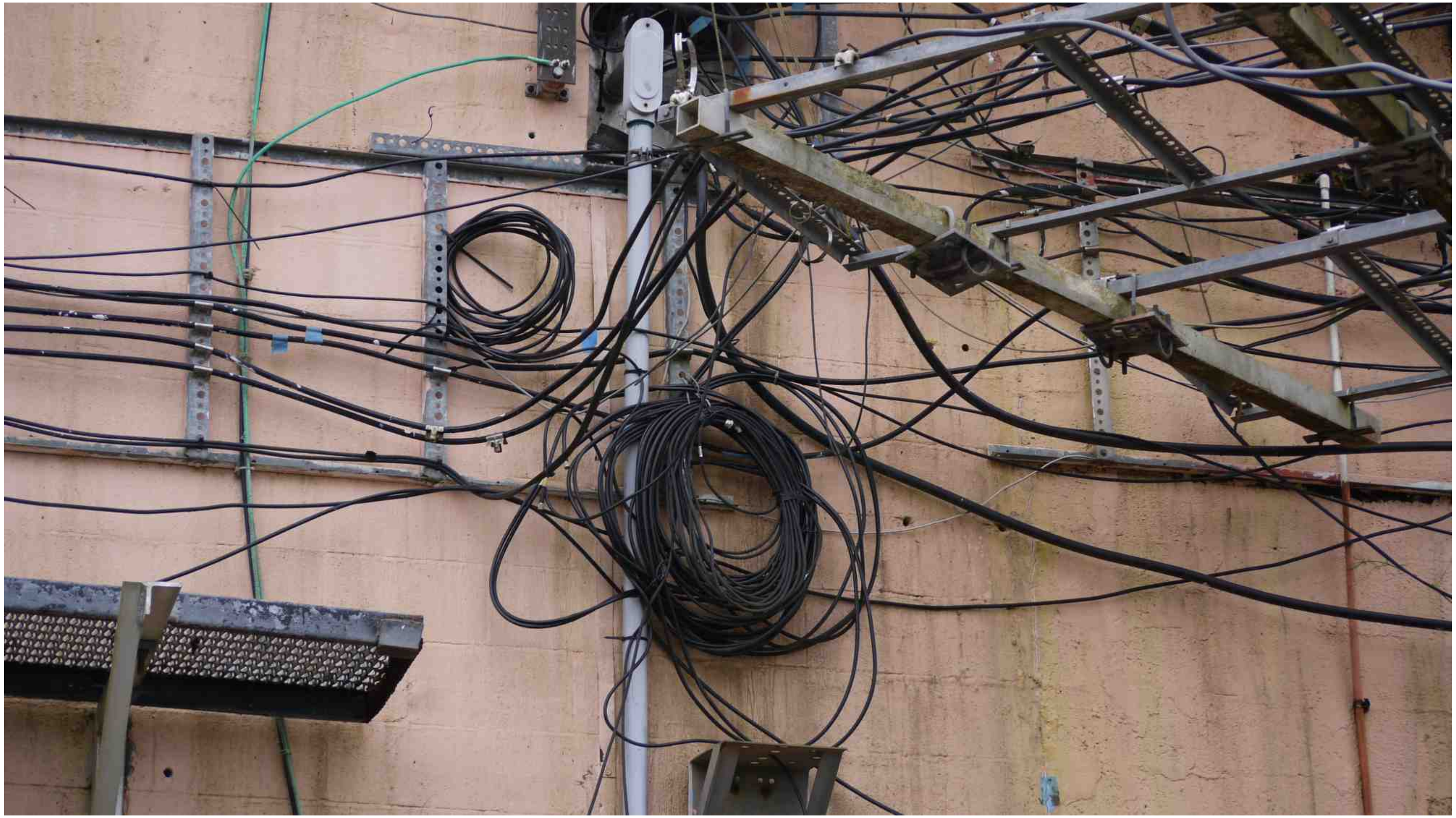
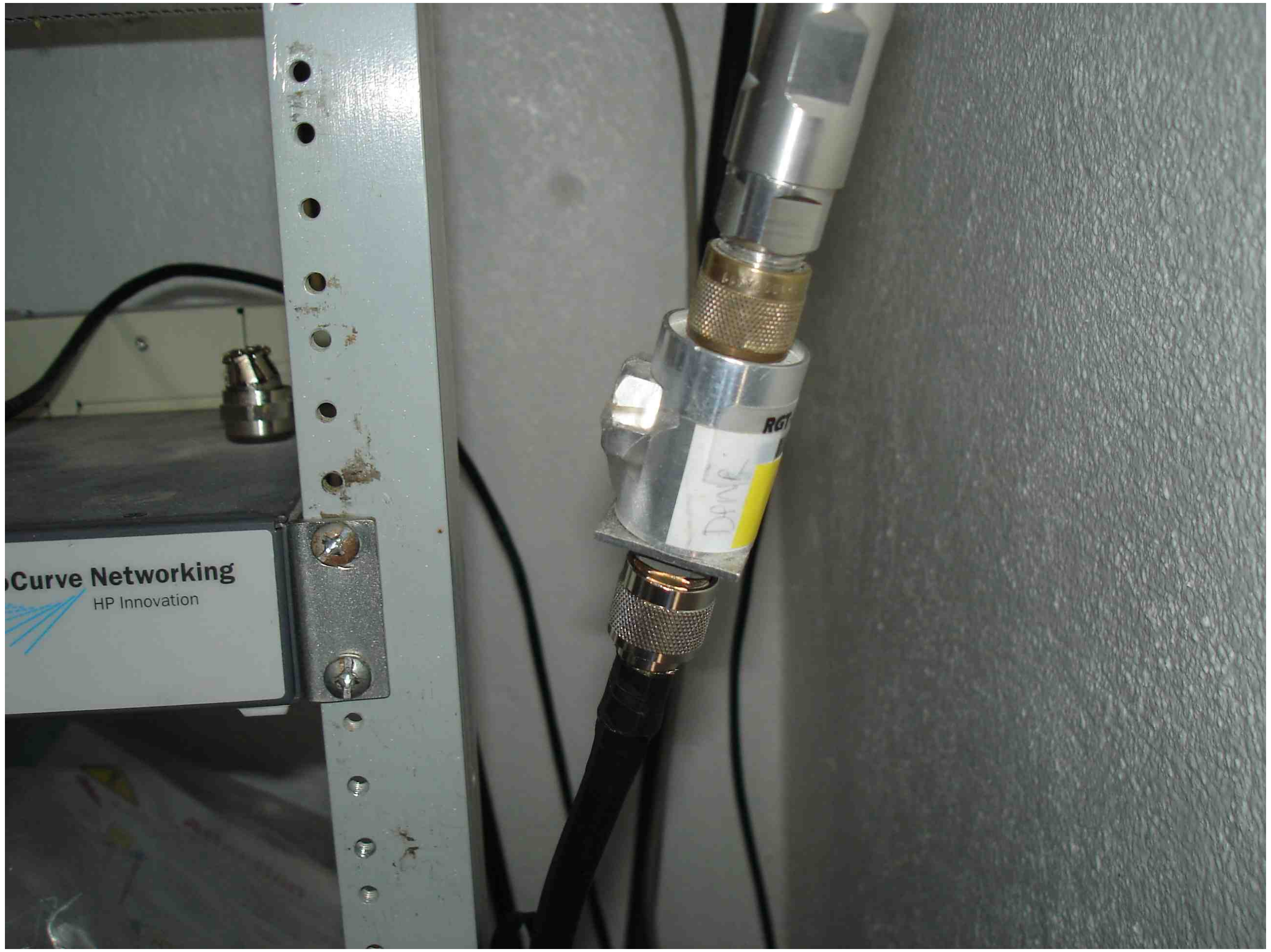


Example Photos



Frequency Stability

The maximum BS transmit frequency error from the assigned RF carrier centre shall be as defined in table 10.1.

Table 10.1: BS transmit frequency error

Frequency range	BS maximum frequency error
50 MHz to 300 MHz	±2 ppm
300 MHz to 600 MHz	±1 ppm
600 MHz to 800 MHz	±0,75 ppm
800 MHz to 1 GHz	±0,3 ppm

The maximum MS transmit frequency error from the assigned RF carrier centre shall be as defined in table 10.2.

Table 10.2: MS transmit frequency error

Frequency range	MS maximum frequency error
50 MHz to 600 MHz	±2 ppm
600 MHz to 1 GHz	±1,5 ppm

The method of measurement is defined in ETSI EN 300 113-1 [1] or ETSI EN 300 390-1 [3].

Frequency Stability

- It has been noted by the presenter that some manufacturers networks performance is significantly affected more by frequency error than others.
- It is certainly worth a test, set a BS to limit of tolerance one way and an MS the other and see how performance degrades.

Modulation Fidelity

- DMR uses 4 level FSK signalling
- 4800 bit symbol rate, each symbol carrying 2 bits of information
- Four frequencies -1944Hz, -648Hz, +648 Hz, +1944Hz used for the 4 FSK levels.
- Special filters used to ensure radio does not over-deviate into adjacent channel (Root Raised Cosine Filter – RRC) and transmission complies with the masks and other essential criteria defined in ETS EN 300 113 and EN 300 390.

Effect of Low Modulation Fidelity

- Equivalent to noisy signal
- Makes it more difficult for receiver to distinguish the correct symbols (closing of the eye).
- Increased BER at lower signal levels
- Reduced range.
- Firmware upgrades and “dodgy” alignment procedures seem to be the major cause.
- Check on a digital test set, analogue test sets will not give the full picture.

FSK Fidelity Examples

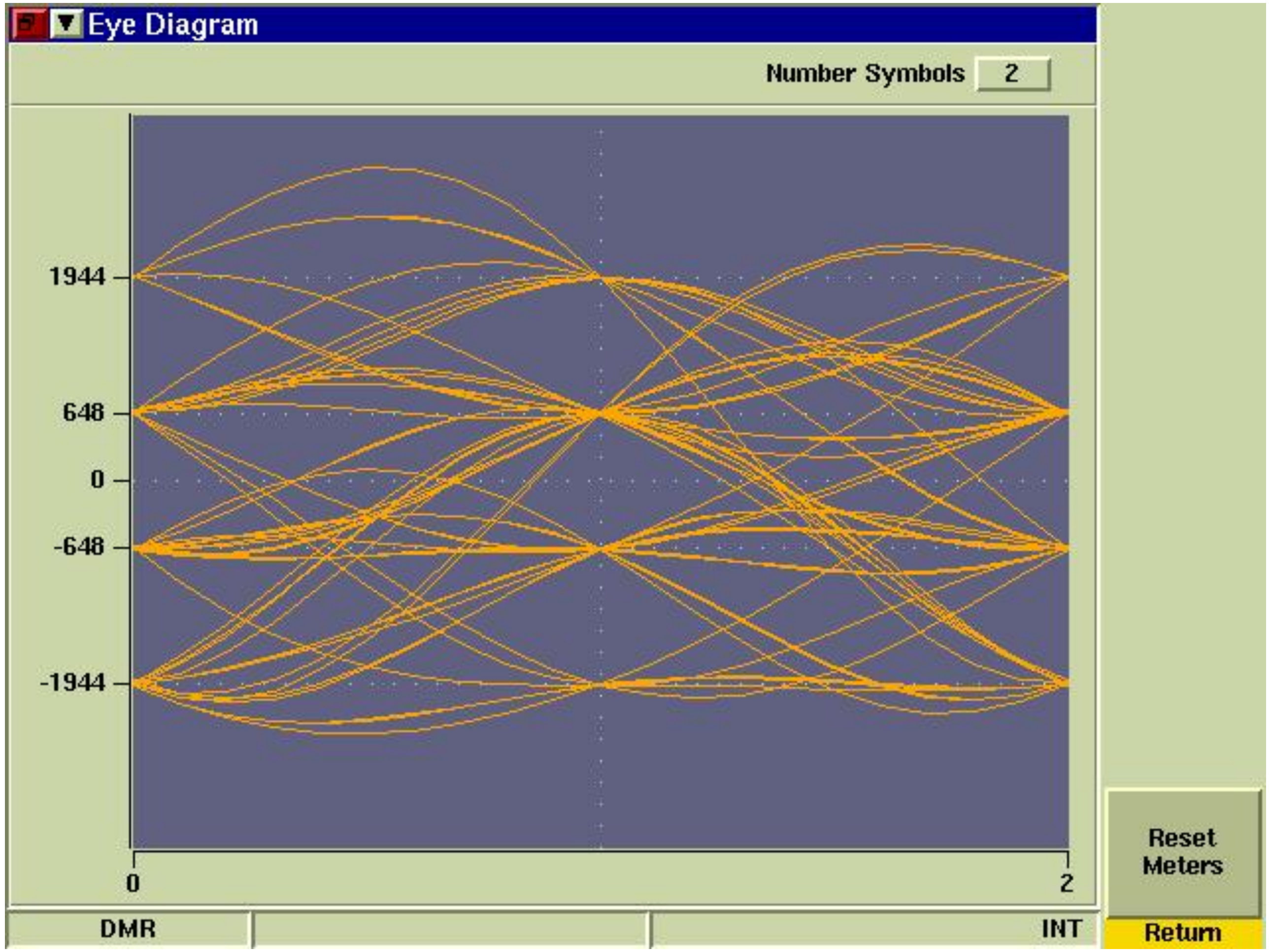
- The following slides are pictures of 4FSK fidelity from different manufacturers MS units.
- An FSK error of <5% is considered a good transmitter.
- FSK magnitude error of <1% is considered to be acceptable.
  - FSK Magnitude error

$$\text{Mag Err (\%)} = \frac{\text{rms [magnitude error at all symbols]}}{\text{rms (envelope)}} \times 100$$

where rms (envelope) = rms of the carrier envelope

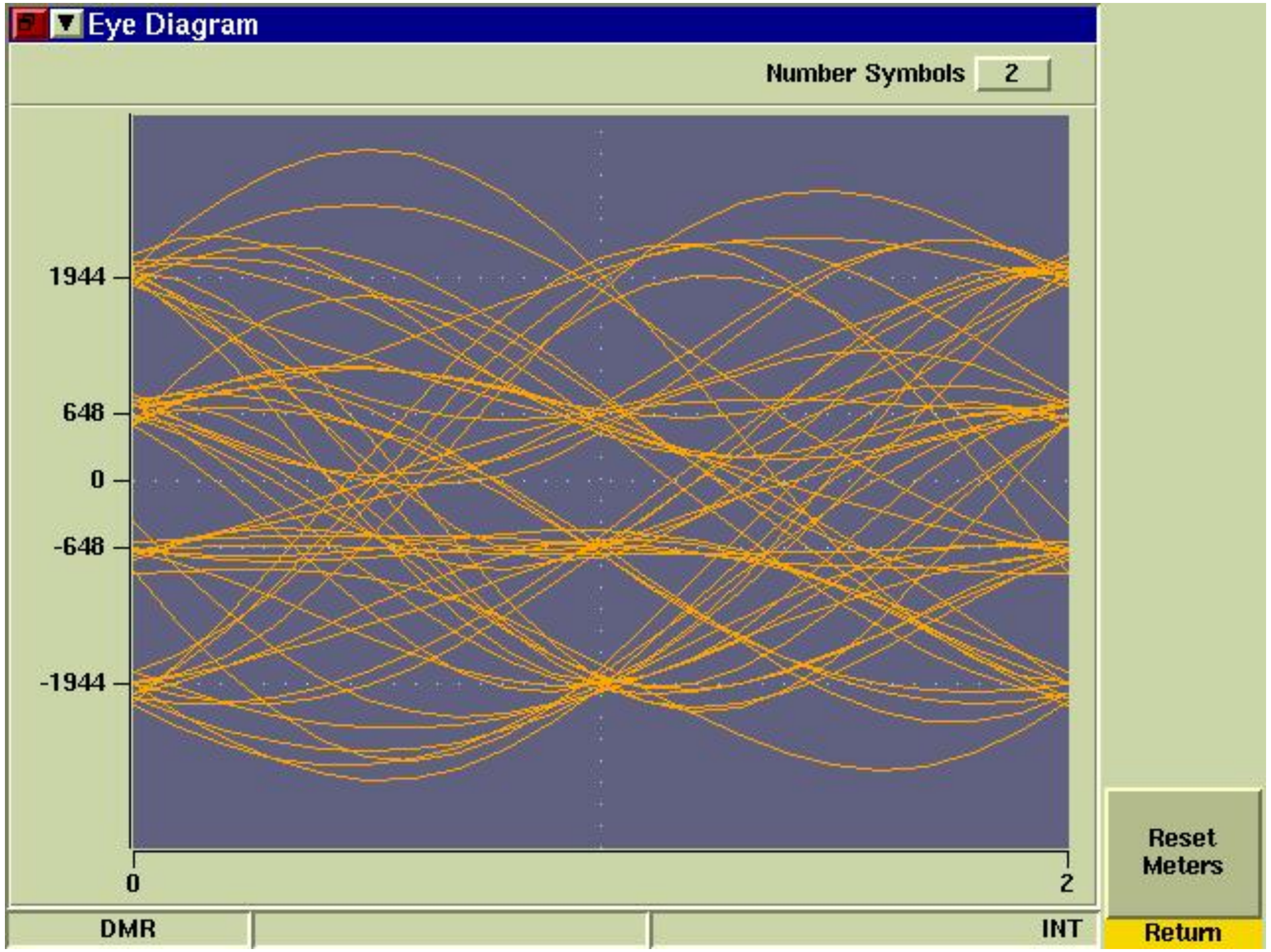
- Symbol clock error rate of upto 48mHz (milli Hertz) is acceptable.

Test Set signal fed back at -60dBm



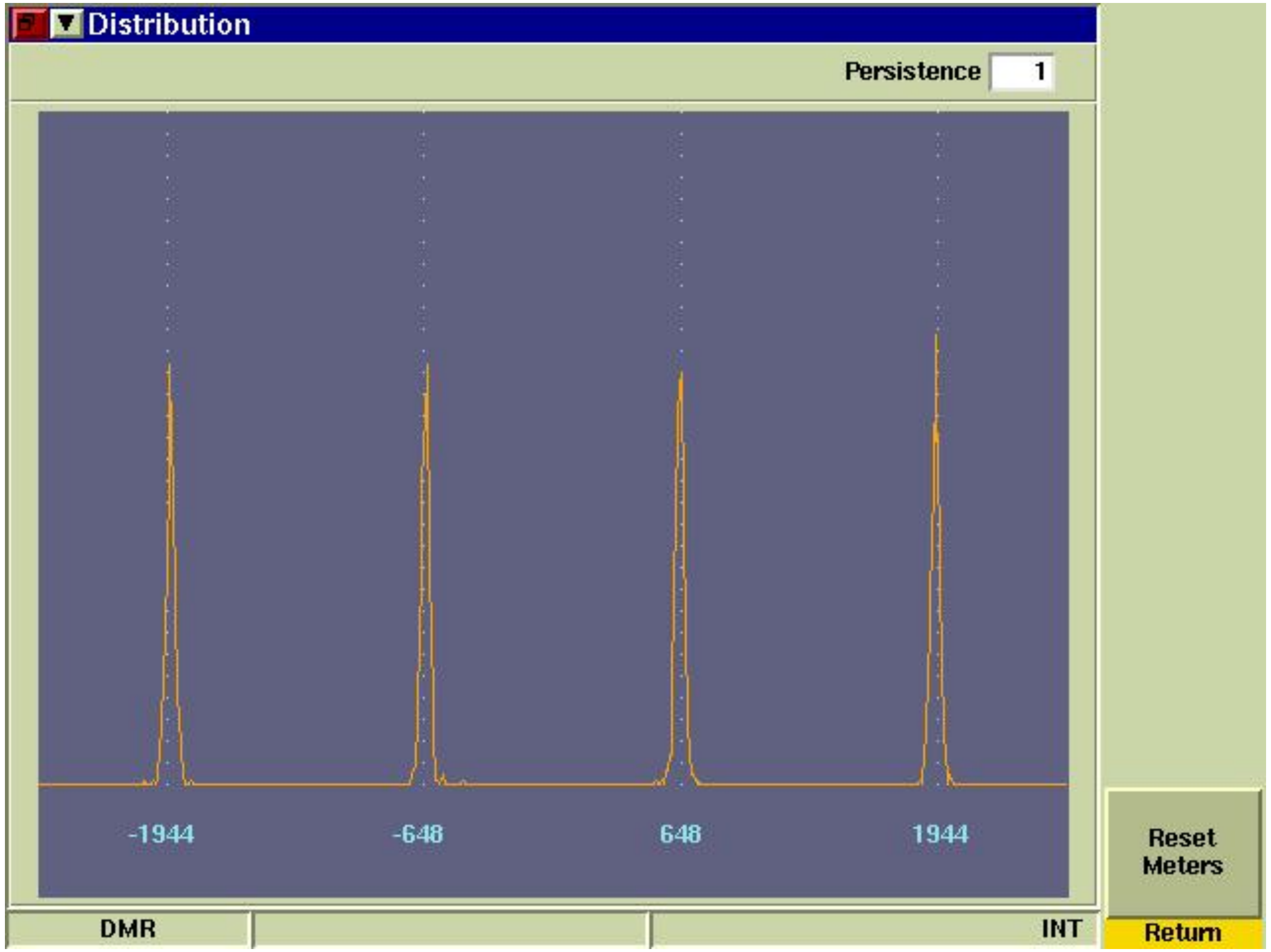
Company General Use

Test Set signal fed back at -105dBm

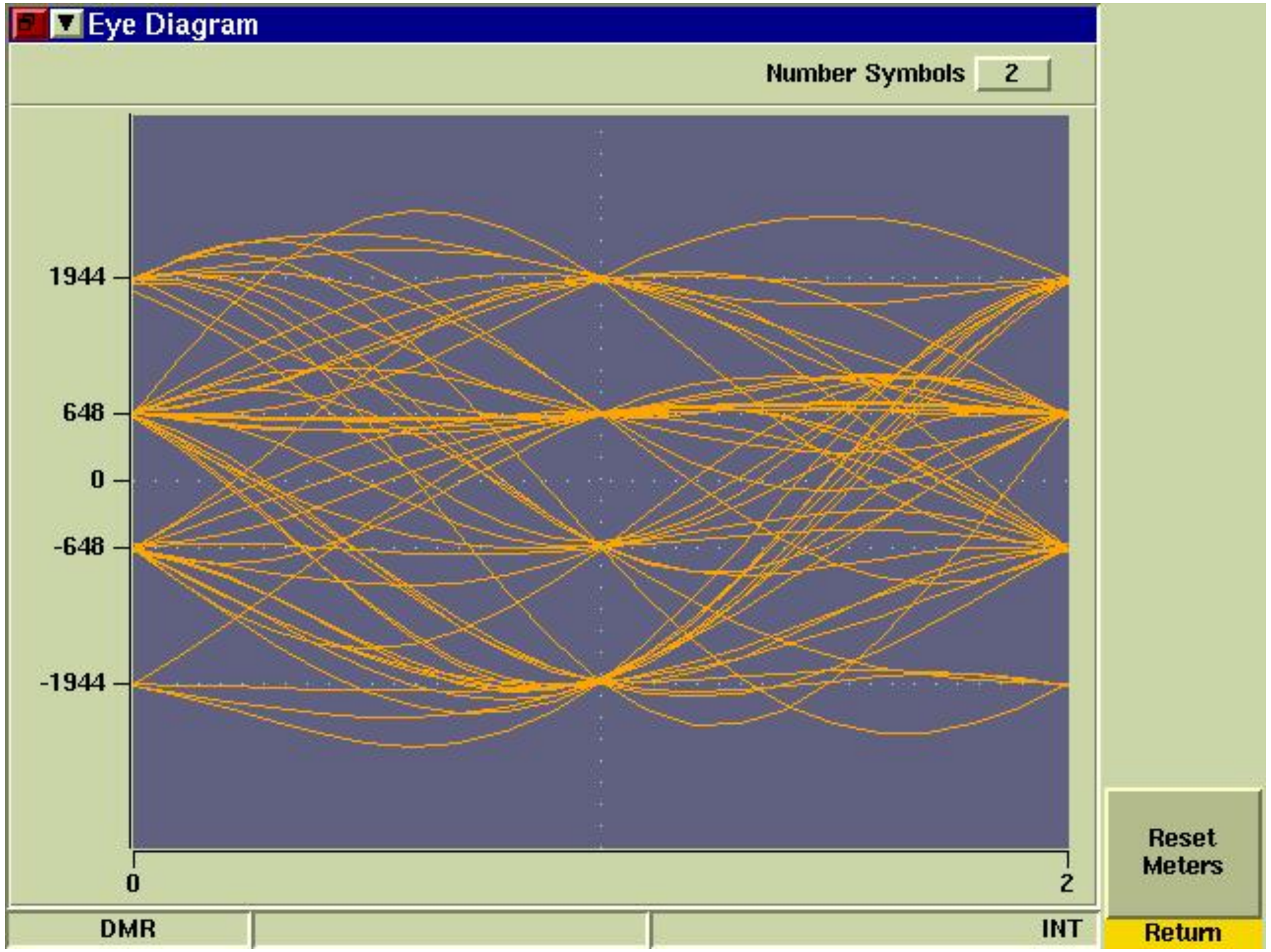


Company General Use

Example A (Distribution).

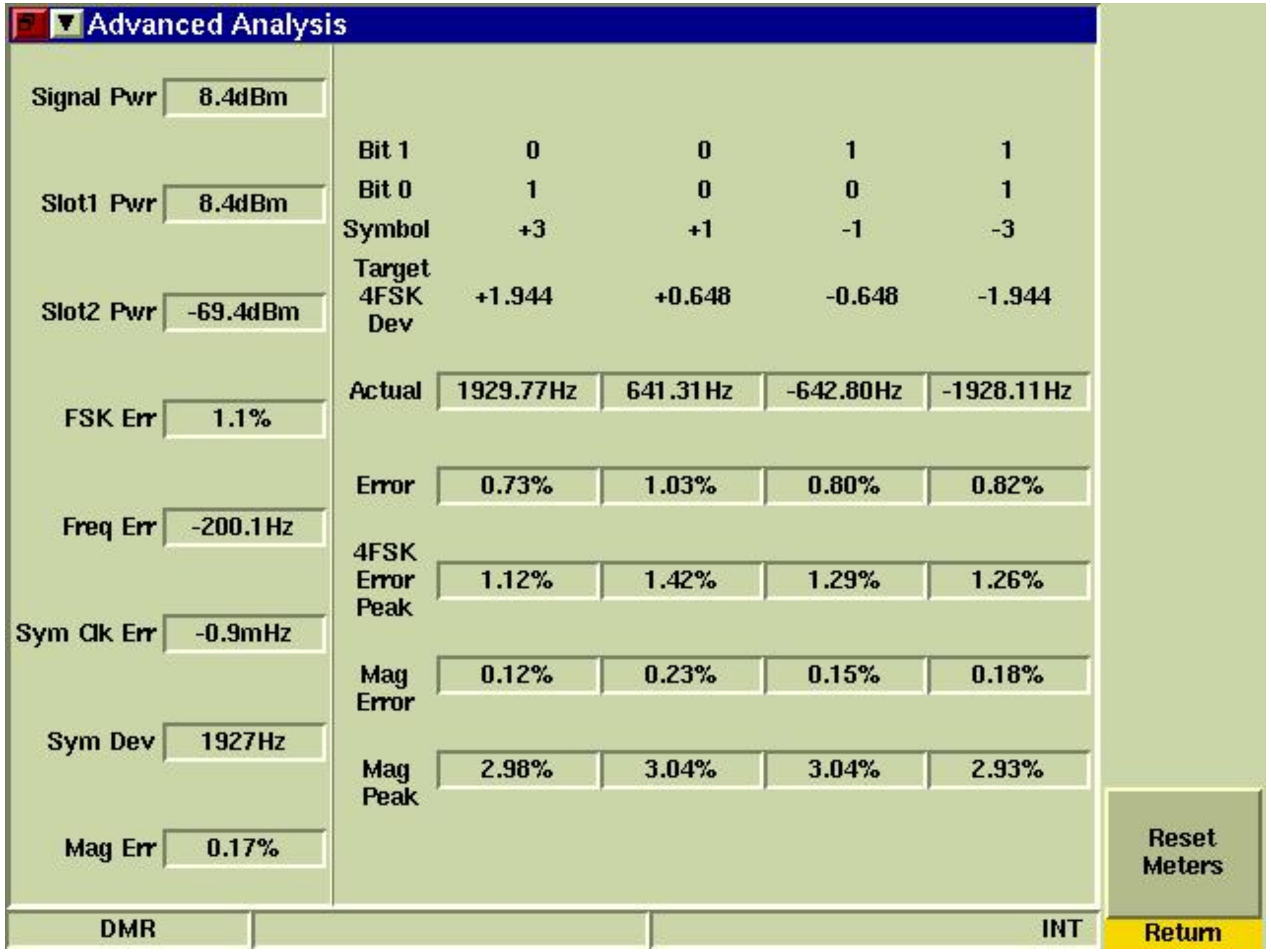


Example A (Eye Diagram)

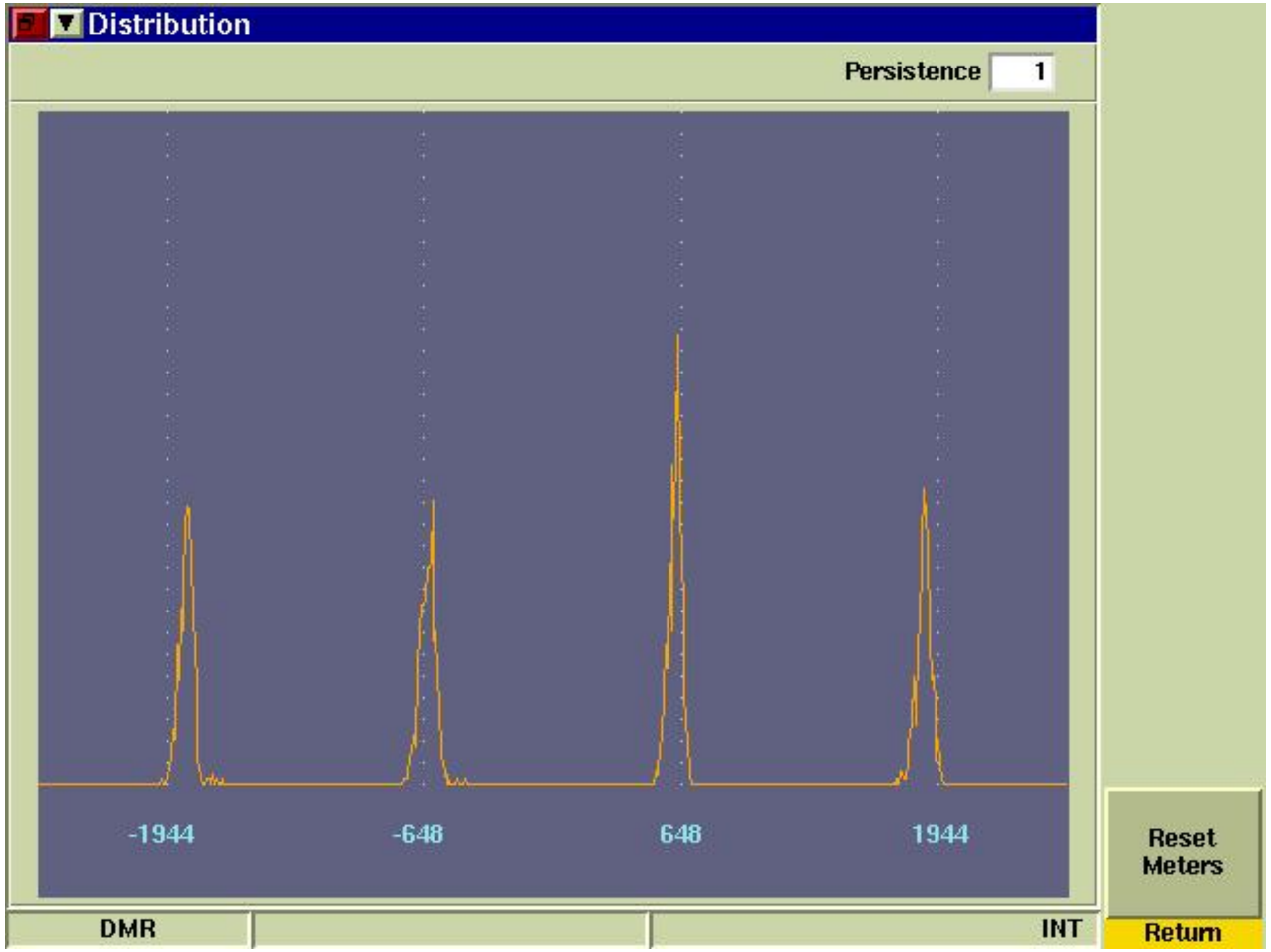


Company General Use

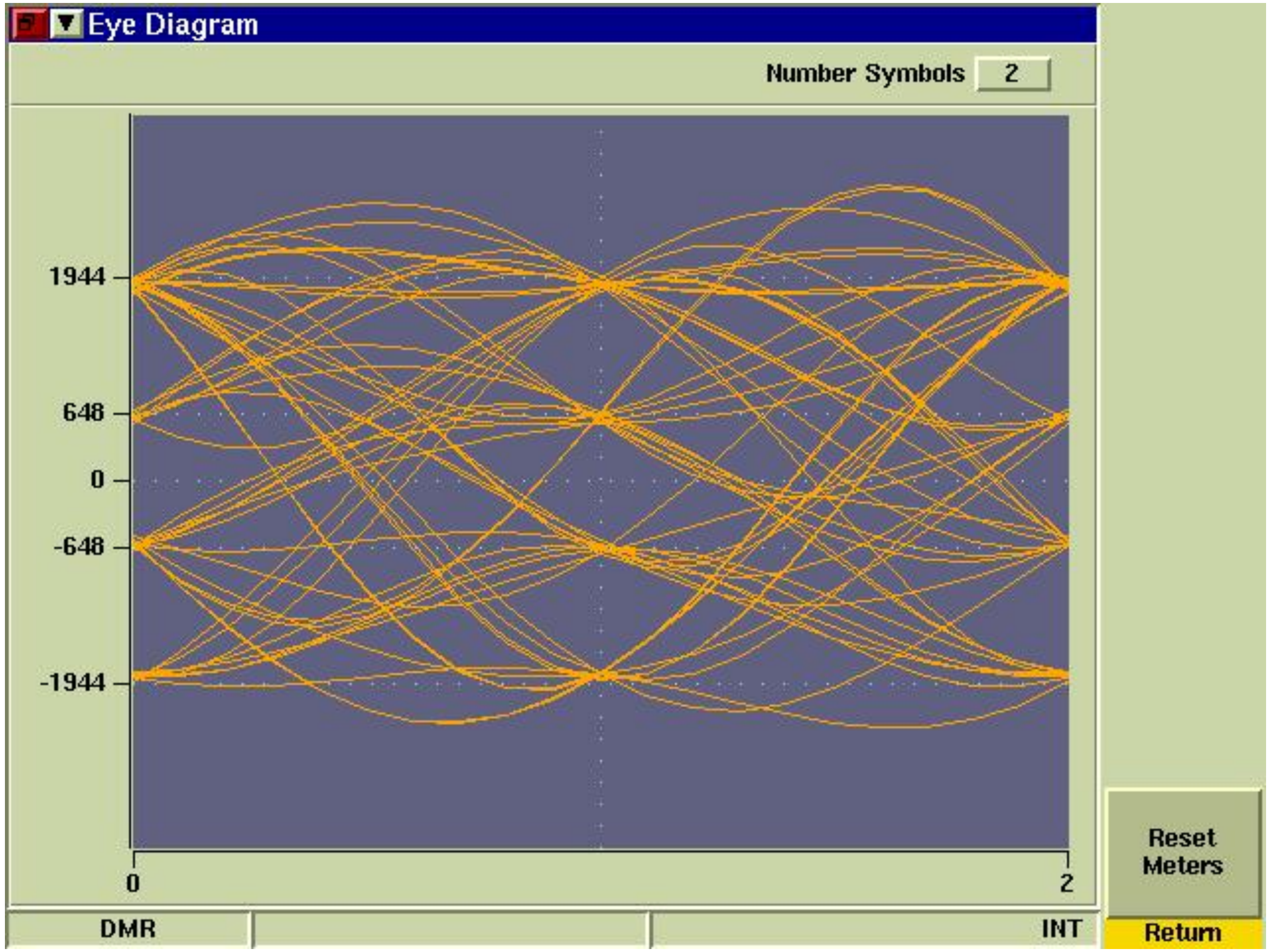
Example A (Advanced Analysis)



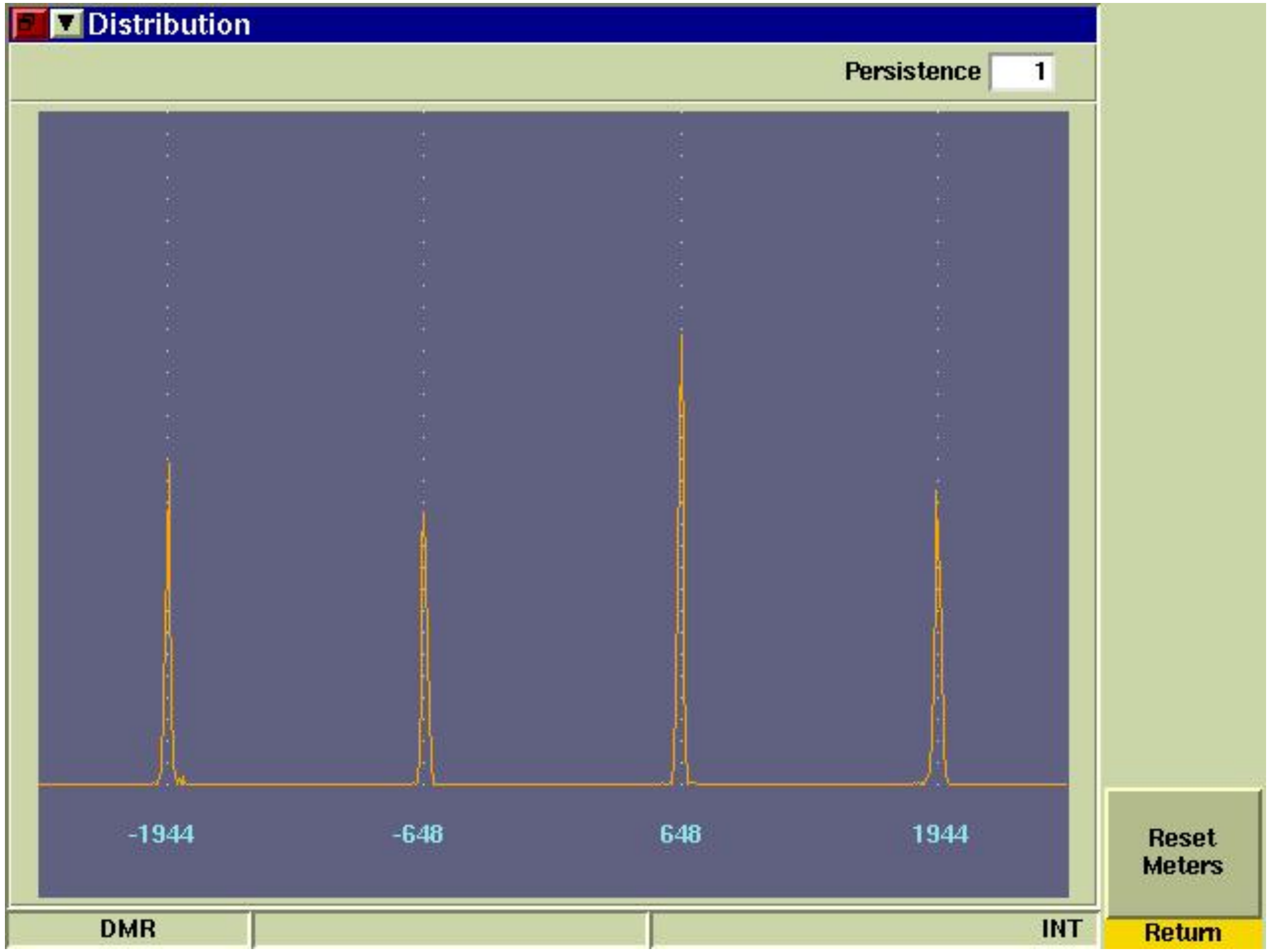
Example B (Eye)



Example B (Eye Diagram)

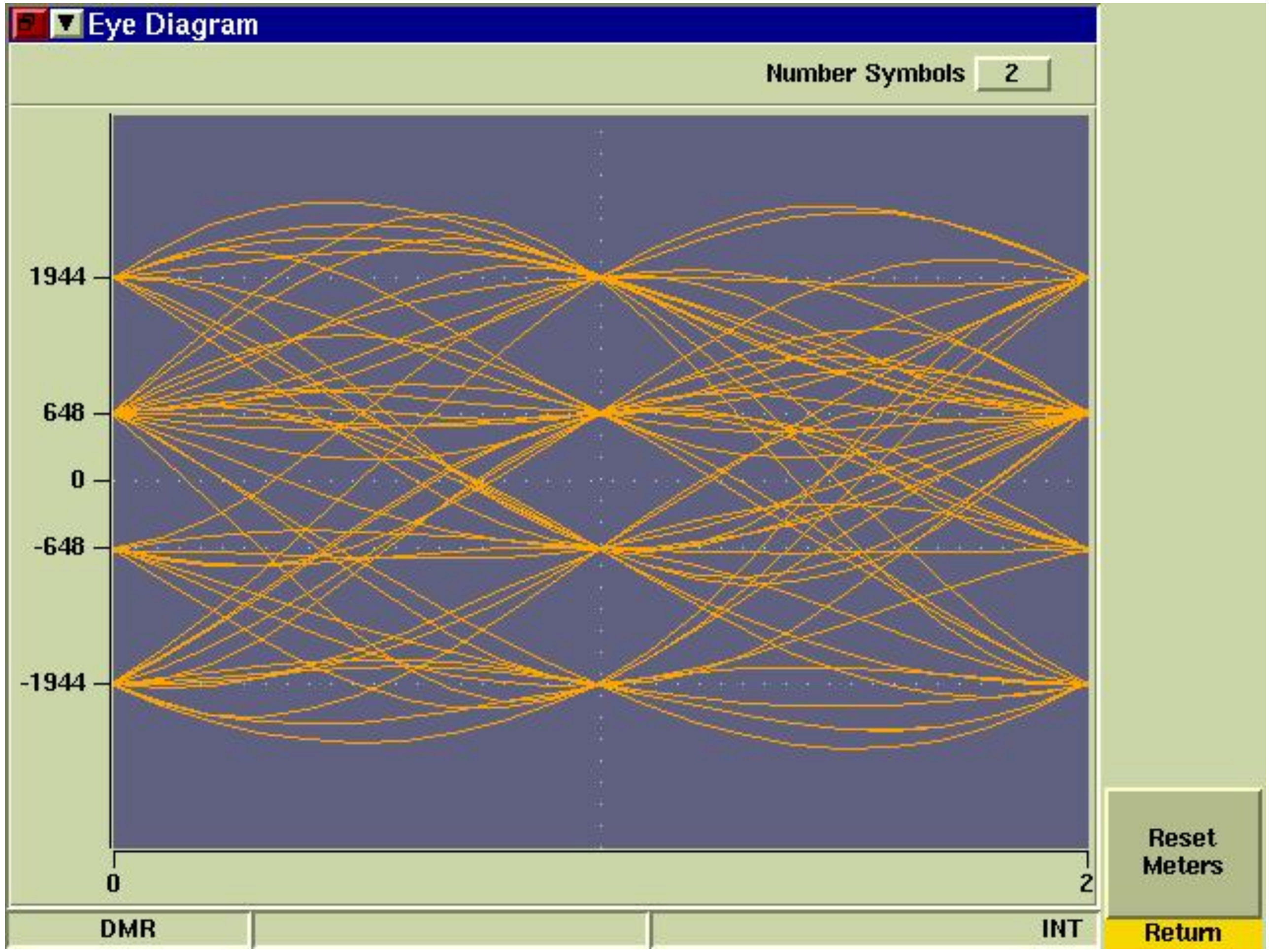


Example C (Distribution)

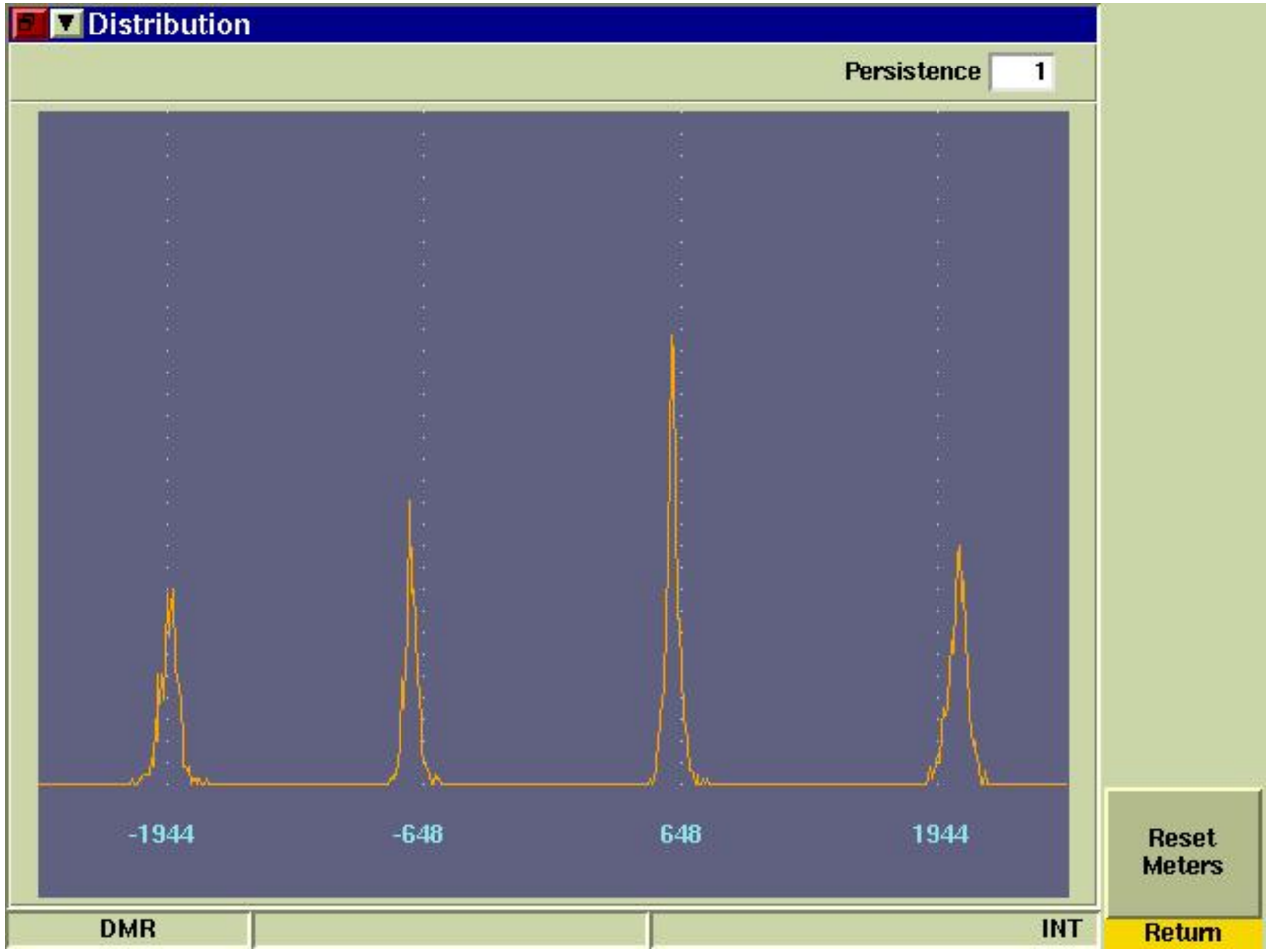


Company General Use

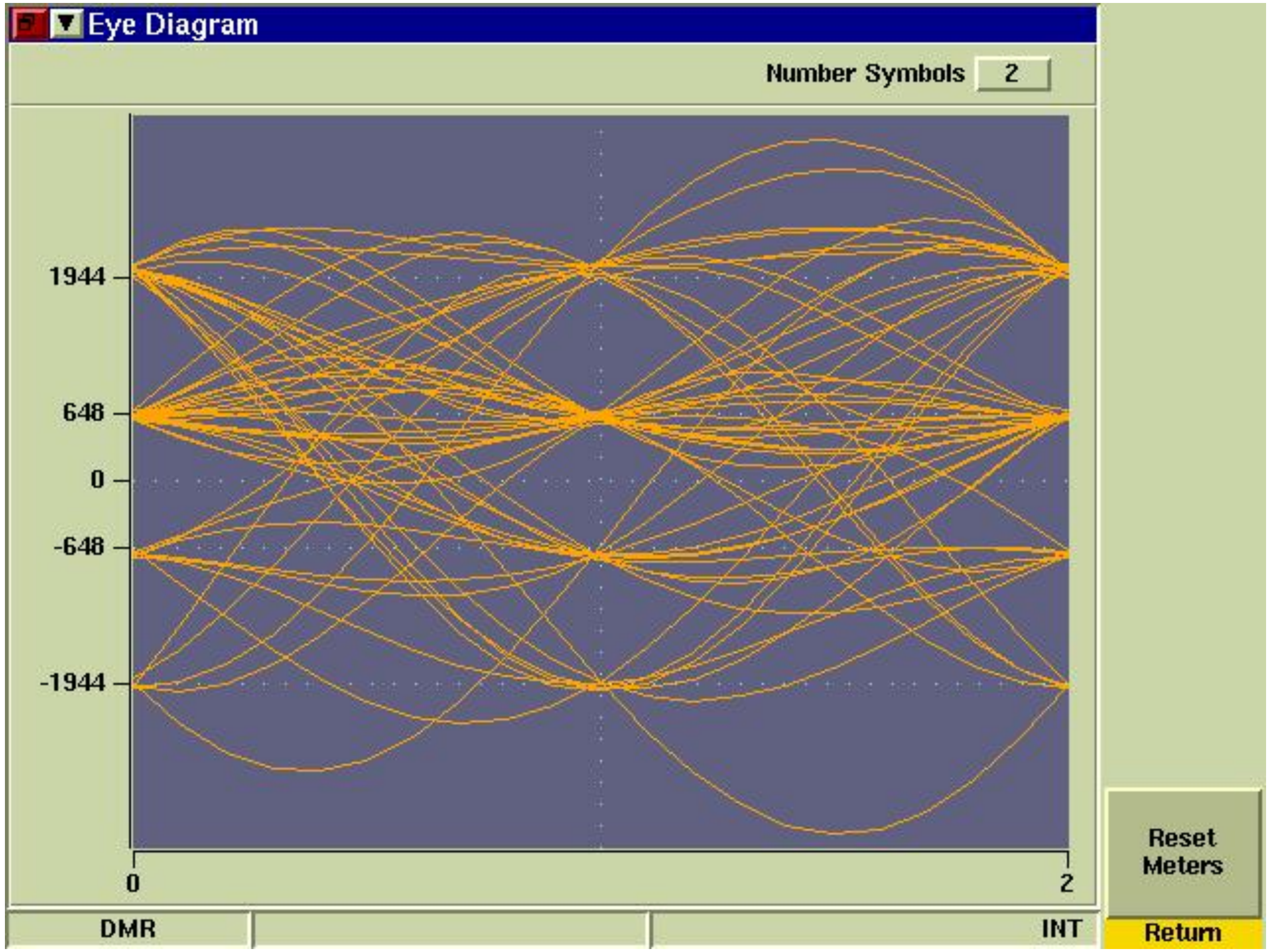
Example C (Eye)



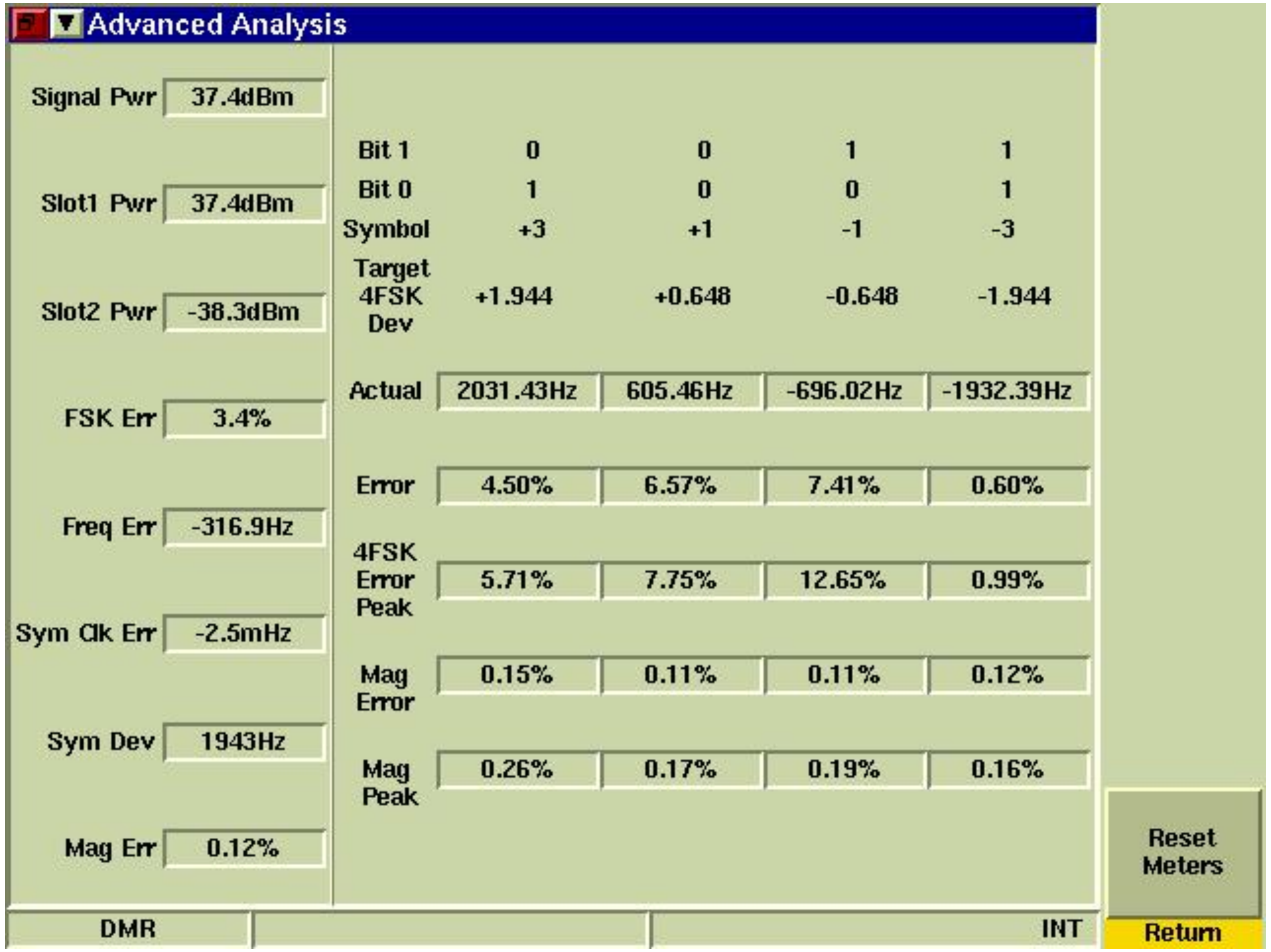
Example D (Distribution)



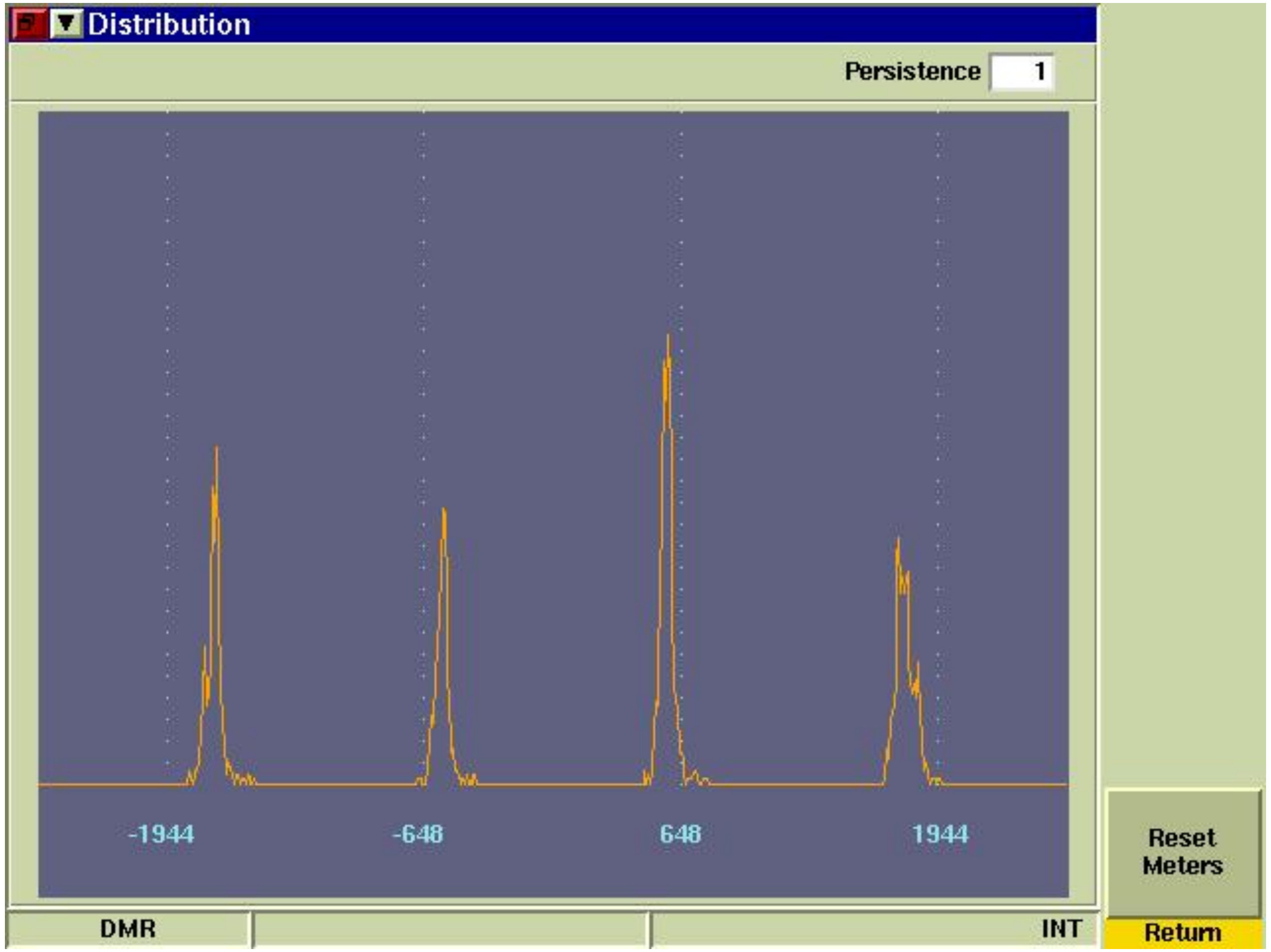
Example D (Eye)



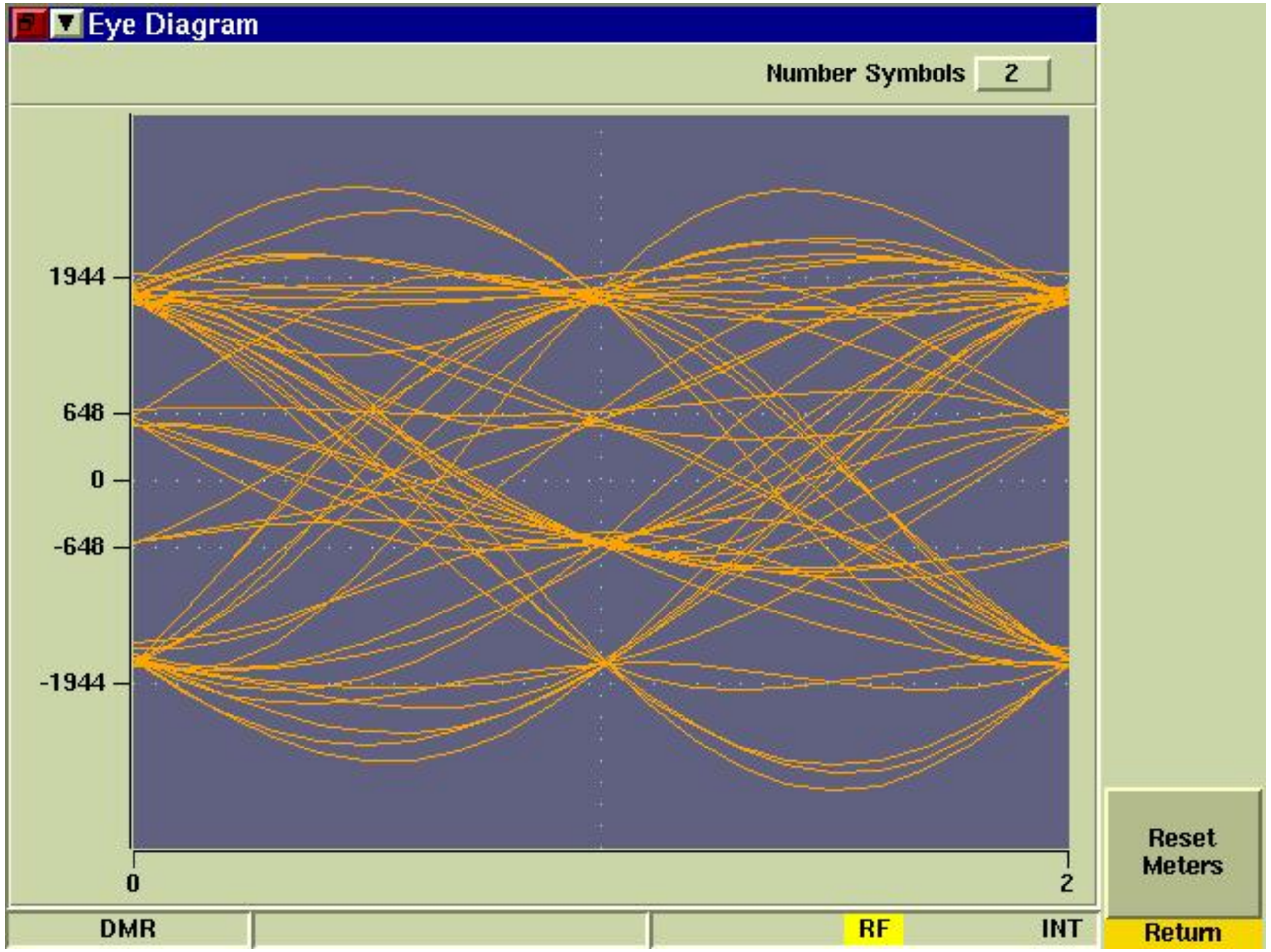
Example D (Advanced Analysis)



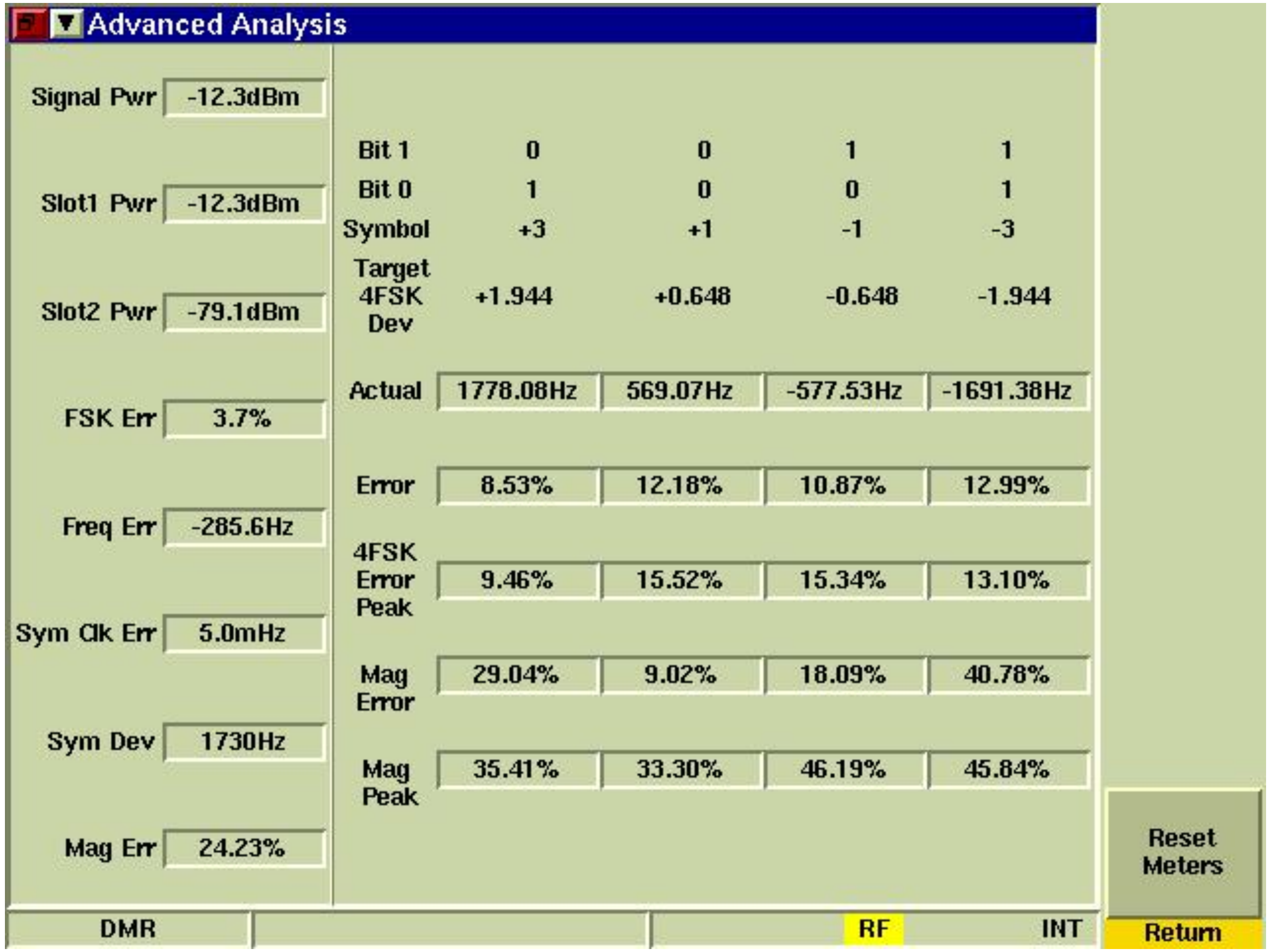
Example E (Distribution)



Example E (Eye)



Example E (Advanced Analysis)



Advanced Analysis

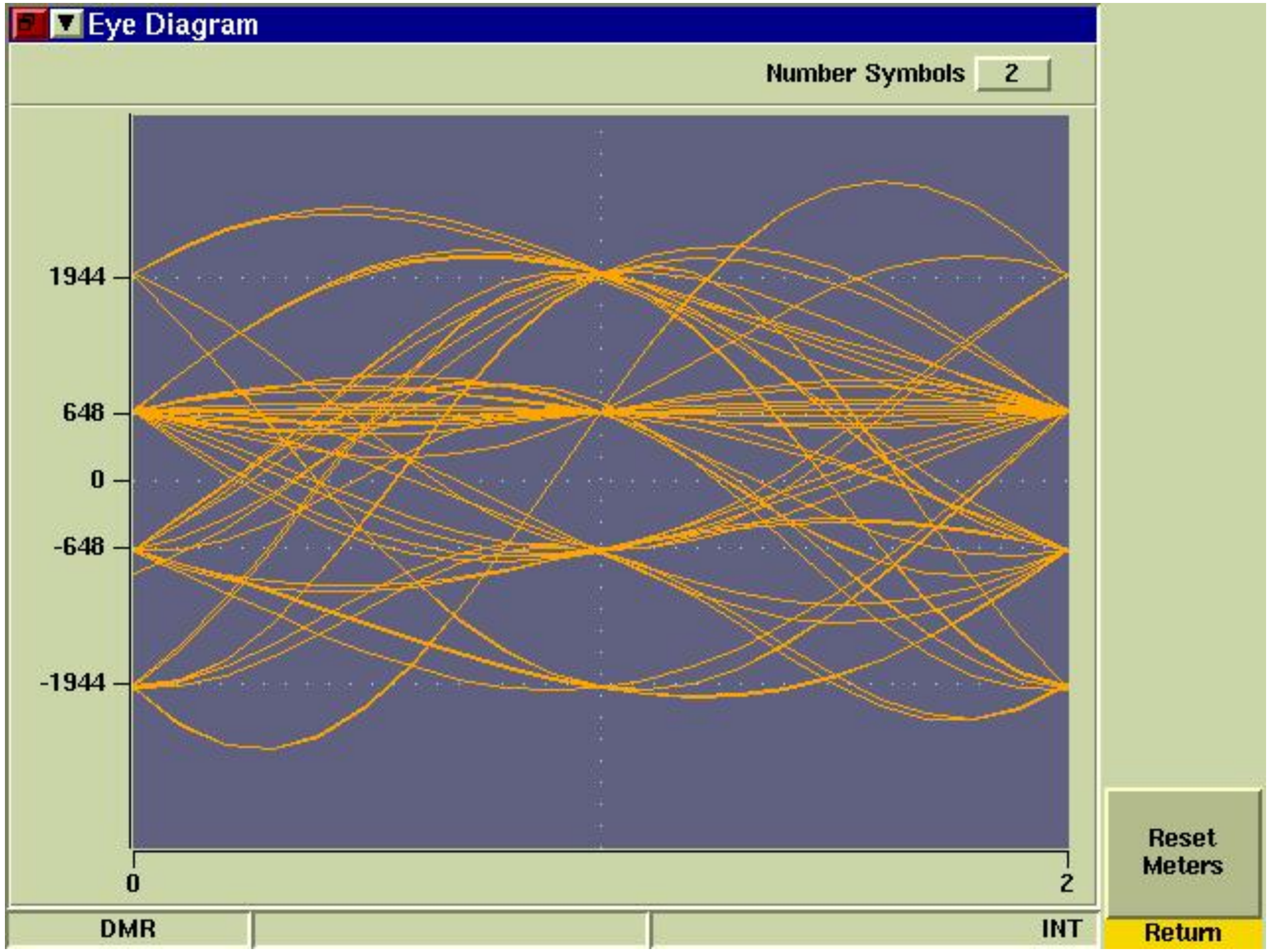
Signal Pwr	-12.3dBm
Slot1 Pwr	-12.3dBm
Slot2 Pwr	-79.1dBm
FSK Err	3.7%
Freq Err	-285.6Hz
Sym Clk Err	5.0mHz
Sym Dev	1730Hz
Mag Err	24.23%

Bit 1	0	0	1	1
Bit 0	1	0	0	1
Symbol	+3	+1	-1	-3
Target 4FSK Dev	+1.944	+0.648	-0.648	-1.944
Actual	1778.08Hz	569.07Hz	-577.53Hz	-1691.38Hz
Error	8.53%	12.18%	10.87%	12.99%
4FSK Error Peak	9.46%	15.52%	15.34%	13.10%
Mag Error	29.04%	9.02%	18.09%	40.78%
Mag Peak	35.41%	33.30%	46.19%	45.84%

Reset Meters

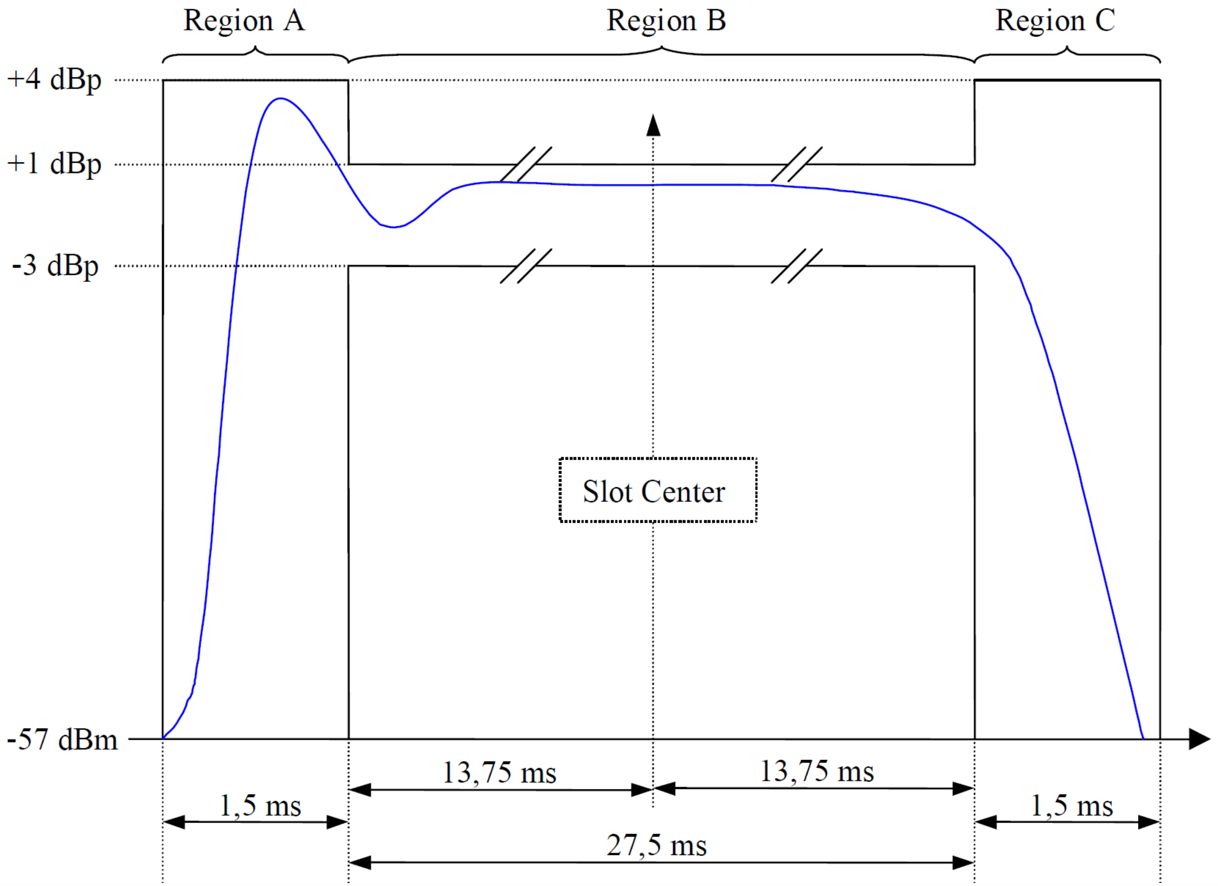
DMR RF INT Return

Example F (Eye)

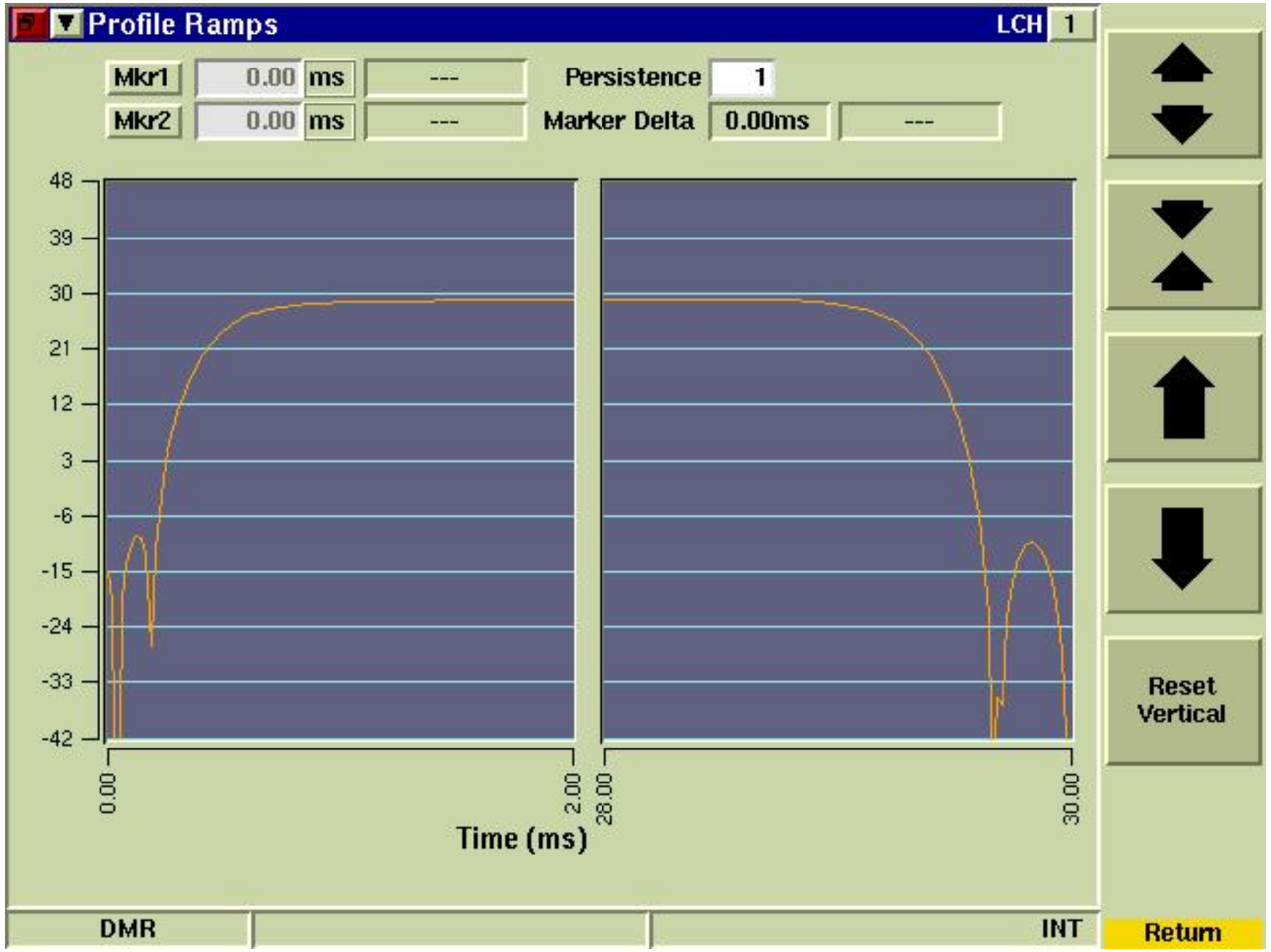


Power Ramp

- The DMR specification defines the power ramp in a timeslot.

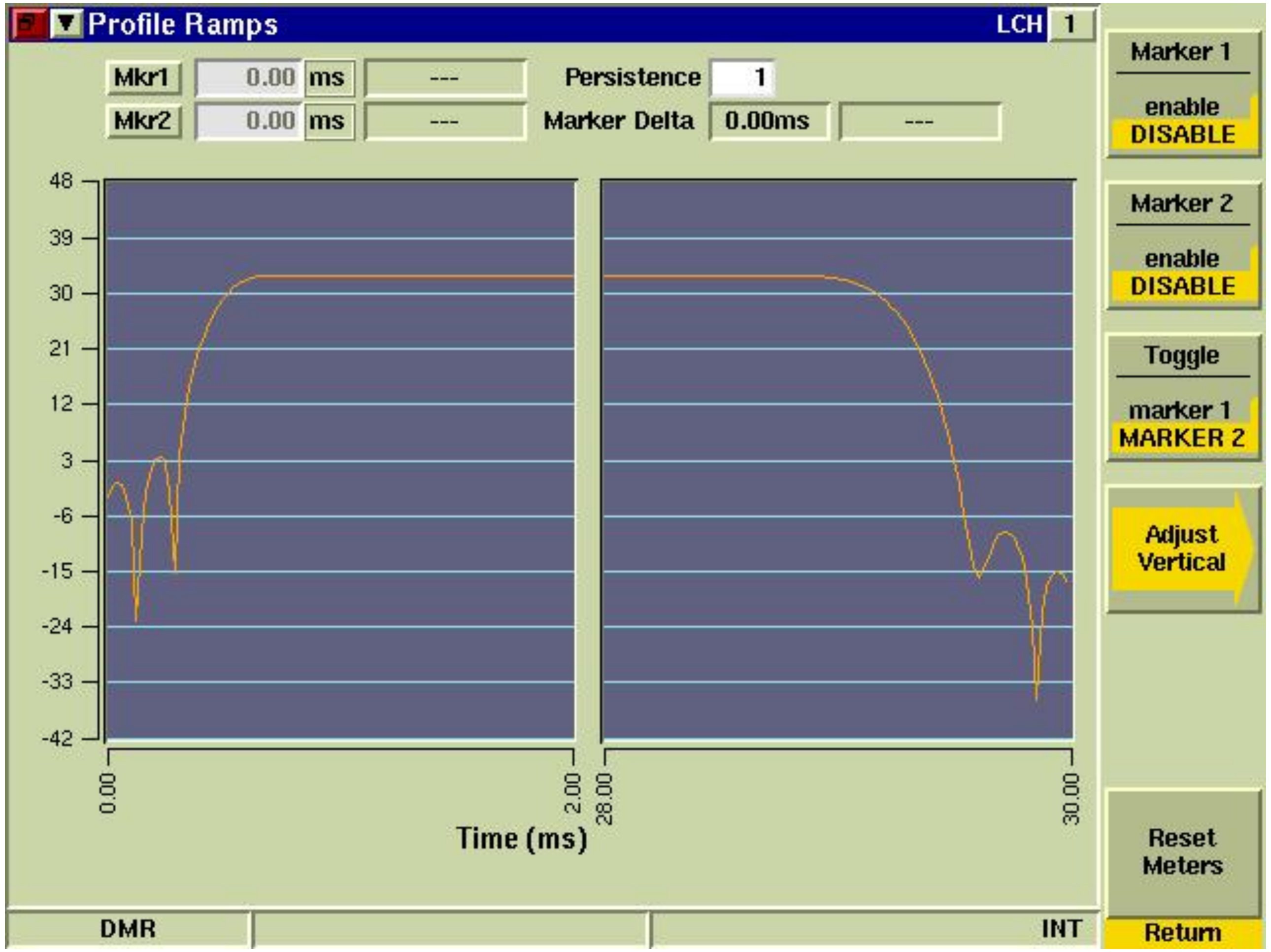


Example A

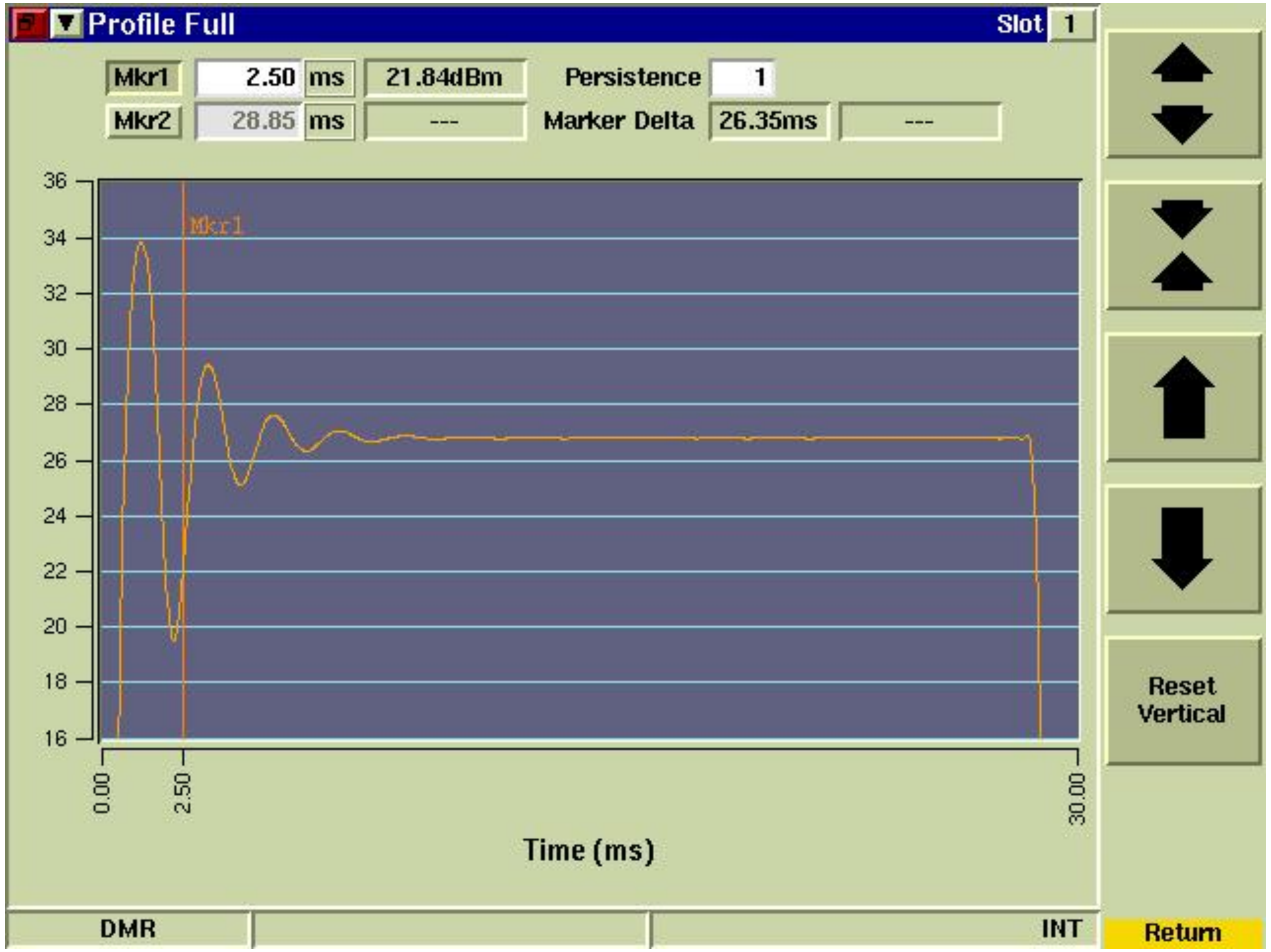


Company General Use

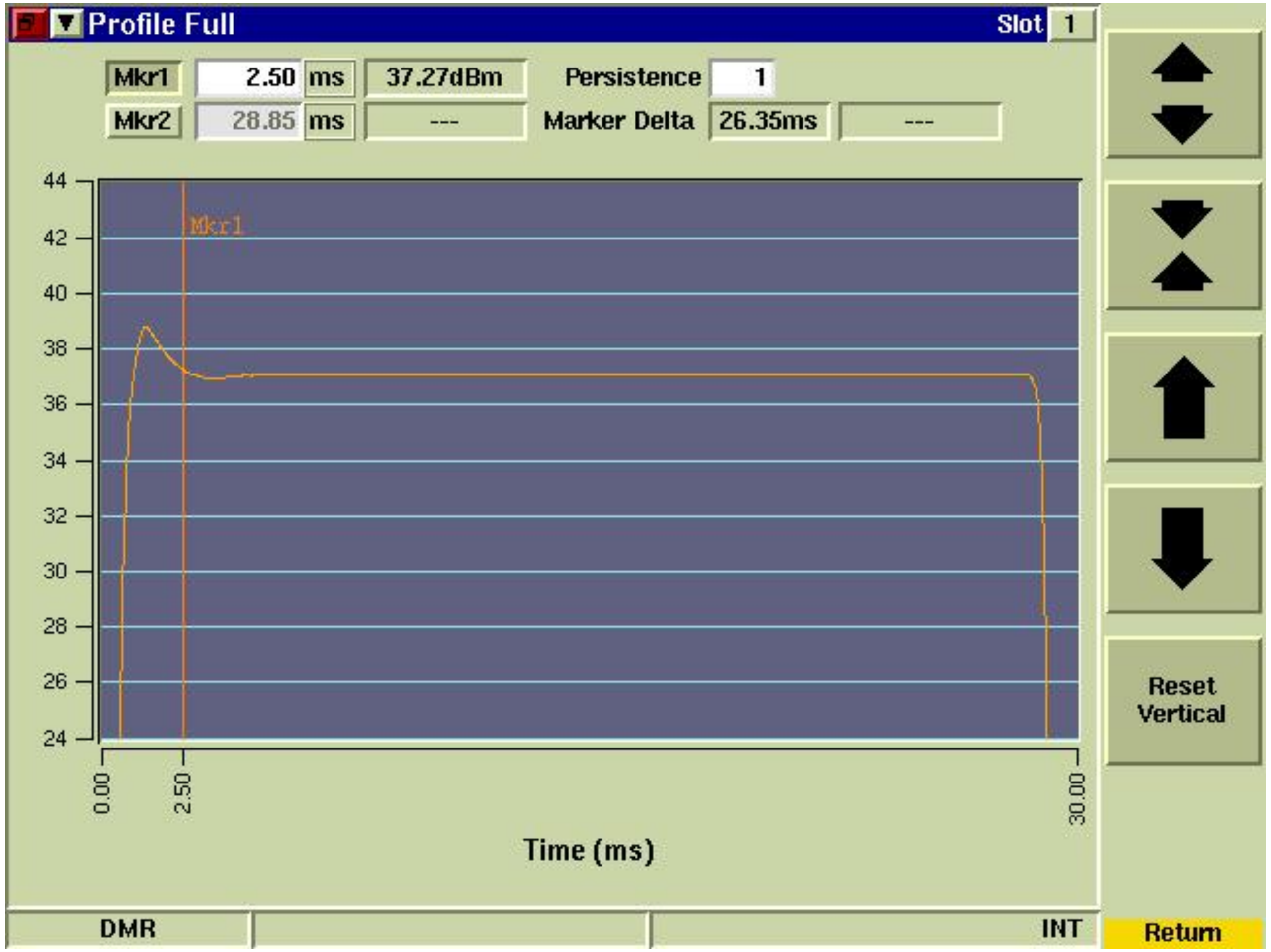
Example C


Profile Ramps
LCH 1
Mkr1 0.00 ms ---
Mkr2 0.00 ms ---
Persistence 1
Marker Delta 0.00ms ---
48
39
30
21
12
3
-6
-15
-24
-33
-42
0.00
2.00
28.00
30.00
Time (ms)
Marker 1
enable
DISABLE
Marker 2
enable
DISABLE
Toggle
marker 1
MARKER 2
Adjust Vertical
Reset Meters
Return
DMR
INT

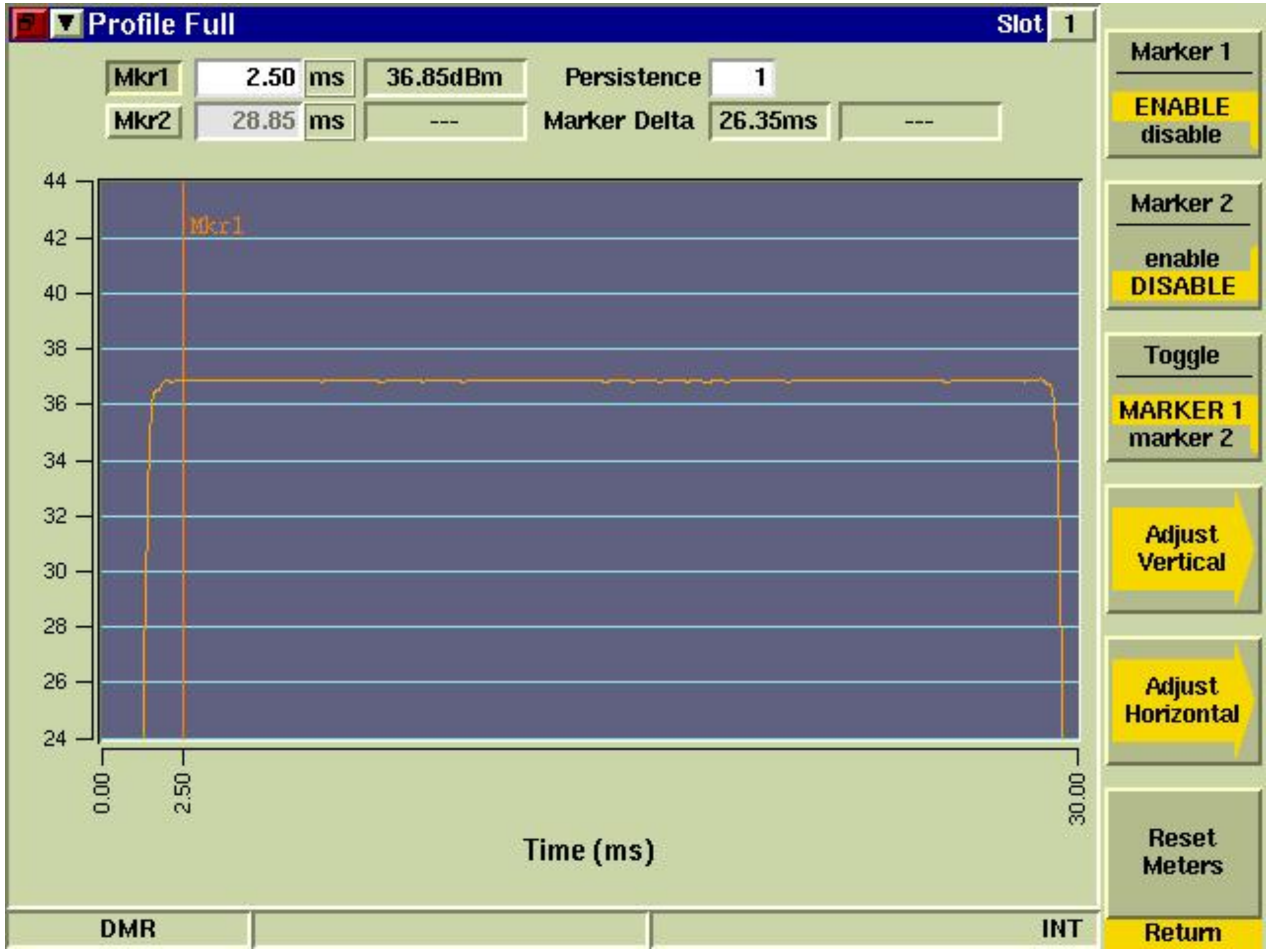
Example E (Oops)



Example E


Profile Full
Slot 1
Mkr1 2.50 ms 37.27dBm
Persistence 1
Mkr2 28.85 ms ---
Marker Delta 26.35ms ---
44
42
40
38
36
34
32
30
28
26
24
Mkr1
0.00
2.50
30.00
Time (ms)
Reset Vertical
DMR
INT
Return

Example F



Company General Use

Reciprocity (or lack of)

- A common problem with DMR, typically the path from the BS to the MS is better than the path MS to BS (especially with portable MS's)
  - MS can hear BS so remains in service but BS cannot hear MS.
- Can be circumvented with careful adjustment of MS transmit powers, down-tilt antenna's and careful use of Vote Now and Adjacent Channel MS functions, though implementations in different manufacturers differ and can be problematic to optimise.

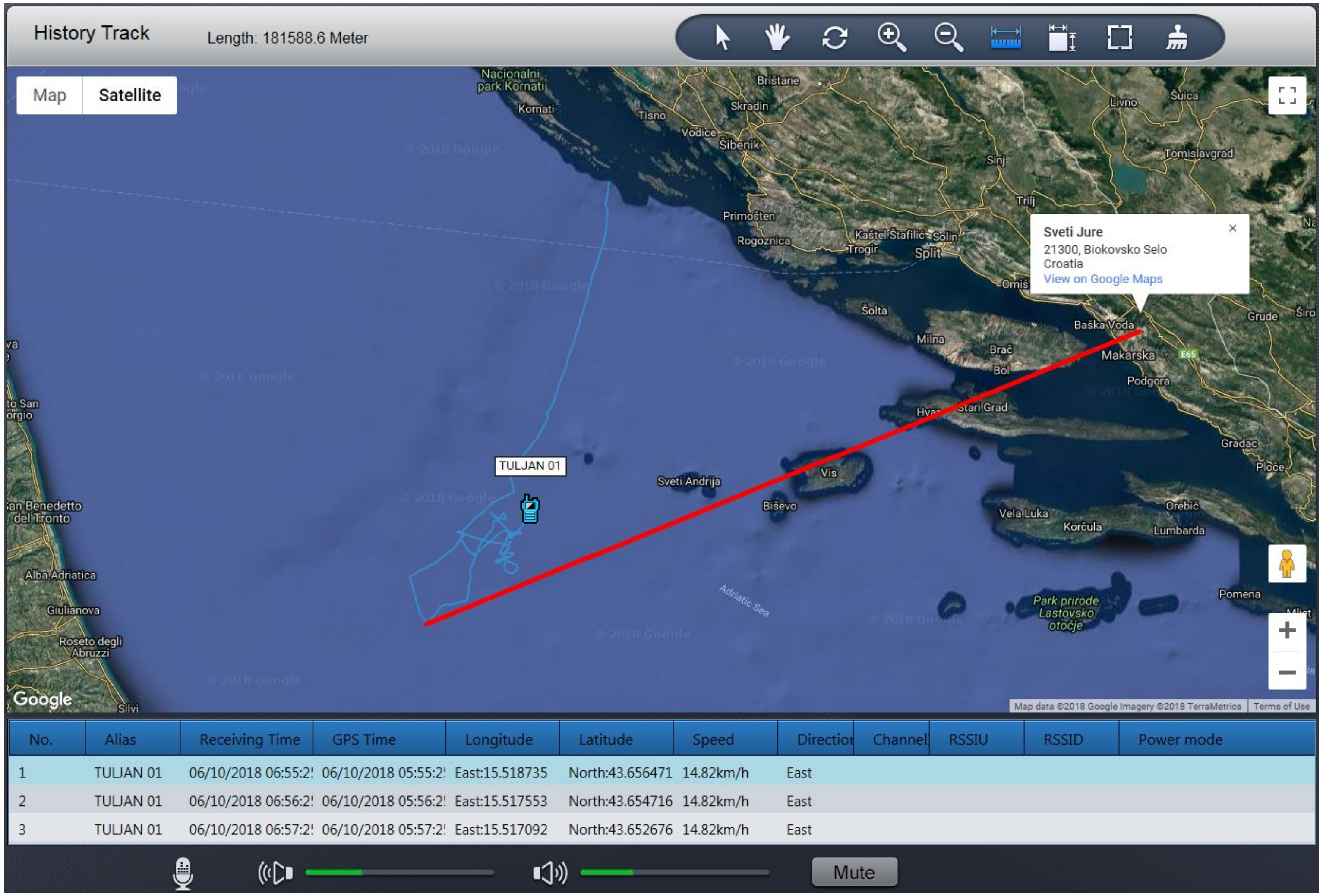
Networks

- Most BS's and central nodes are connected together via IP networks using private and sometimes public networks.
- When calculating the IP bandwidth required from the BS to central node or other BS remember the various overheads the signalling layers add. RTP and UDP/TCP headers can significantly add to the required bandwidth. Some manufacturers do not include this in their bandwidth statements.
- Jitter is the enemy of reliable voice transmission. Some networks allow jitter buffers to be optimised, increase the size of the jitter buffers should reduce any IP dropped packets but will increase the speech delay.

In Summary

- Minimise BS noise floor by sensible site location, good site engineering, grounding etc, and look out for potential noise sources.
- Check BS and MS frequency alignment and modulation fidelity properly (using digital test set).
- Check reciprocity from BS and optimise coverage/adjust BS output power.
- Take time to correctly set vote now and adjacent site MS parameters (background hunt levels etc)
- Check network jitter and adjust jitter buffers accordingly.

And Finally: what can be achieved



. This customer was able to make a group call with a DMR hand-held terminal on a boat distanced ~182 km from the BS with perfect audio quality.

DMR

Thank you!

For more info: twgchair@dmrassociation.org