

FIBRE-OPTIC LINKS


-An Introduction

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**Atacama
Large
Millimeter
Array**

--The use of fibre optics in the ALMA IF data transmission system


Back End Preliminary Design Review, 2002 April 24-25, Granada, Spain



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JBO involvement in fibre-optic data transmission

- History: collaboration with BT Labs, Martlesham on 200 km analogue links 1997-1999 (L. Hu)
- Fibre-optic lab set up at JBO 1999-2000
- Feasibility study on fibre links for EVN 1999-2000 (B. Smith)
- e-MERLIN fibres 2002--
- ALMA phase 1 development (R. McCool) 2000--
- Laboratory based test link 2002-2003 (funded)
- ALMA phase 2 production 2003-- ???


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Technical Objectives of the ALMA IF Data Transfer Link

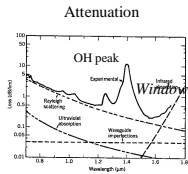
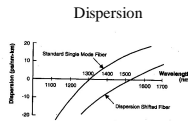
- IF data transfer links are required to transfer 4x2 GHz bands, with 2 polarisations, over ~25 km
- After digitisation and encoding, the system carries 12 optical signals each modulated at 10 Gbit/s (120 Gbit/sec total) using Wavelength Division Multiplexing (WDM)
- Maximum bit error rate of 10^{-6}

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Fibre Link Design

- The link design is constrained by fibre transmission characteristics such as *attenuation* and *dispersion*, which are dependant on length.
- Error rates depend on signal:noise and distortion due to dispersion.
- Non-linear effects restrict total input power to < few mW. In WDM four wave mixing etc. gives cross-talk between channels.


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Properties of links:

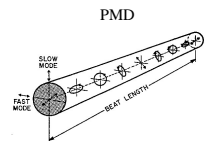
- Typical loss of fibre = 0.25 dB/km at $1550 \text{ nm } \lambda$.
- Dispersion:
 - Standard Single Mode Fibre (SSMF) = 17 ps/km/nm
 - Near Zero Dispersion Shifted Fibre (NZDSF) = 4 ps/km/nm
- Power output of standard commercial 10 Gbps laser diode+modulators is 1 mW (0 dBm)
- Typical pin photodiode receiver sensitivity for 10^{-10} error rate is 10^{-2} mW . (-20 dBm)

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Limits of 10 Gbps transmission over fibre:

- Attenuation - overcome by using Erbium Doped Fibre Amplifiers (EDFAs)
- Dispersion – not a problem for ALMA, NZDSF and dispersion compensation methods can be used for longer links
- Polarisation Mode Dispersion (PMD) - Fibre is birefringent and paths vary continuously giving rise to timing jitter. Not a problem for ALMA




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Bit Error Rates (1)

- Presence of noise and inter-symbol interference gives bit errors
- Photon counting noise is Poisson distributed, the Normal distribution is a good approximation in usual communication systems
- Hence the bit error rate (BER) is given by the area under a Gaussian i.e. the complementary error function

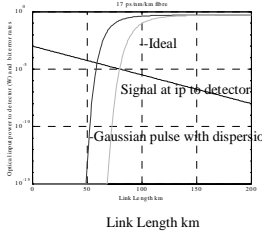
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BER (2): Errors vs Link length


$$BER = 0.5 \times \operatorname{erfc} \left(\frac{S}{\sqrt{2}} \right)$$

S = Optical Signal:Noise Ratio = Q (as used by Rosh and Marcuse)



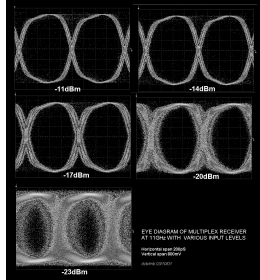
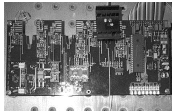
Marcuse, 1991, J. Lightwave Tech, 9, 505
Elrefaie et al., 1988, J. Lightwave Tech, 6, 704

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BER (3): Effects of signal/noise ratio:

-Eye diagram for 10 Gbps data transmission in the lab (phase switched 5 GHz signal).
-Using Multiplex pin diode detector as for ALMA

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What comes next:

- Rosh McCool will go into the link design and overall system functionality in more detail
- Bryan Anderson will discuss hardware designs
- Mike Bentley and Dave Brown (engineers actually designing and prototyping) are in the audience to answer detailed questions

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