INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SECOND WORKSHOP ON

OPTICAL FIBRE COMMUNICATION

(14 - 25 March 1988)

COHERENT SYSTEMS TECHNOLOGIES

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British Telecom Research Labs.
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COHERENT SYSTEMS TECHNOLOGIES

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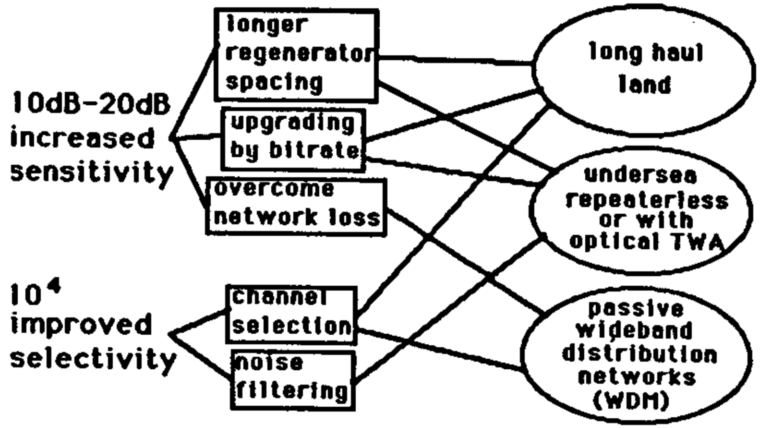
United Kingdom

OUTLINE OF TUTORIAL

INTRODUCTION	: Potential : Principles : Problems
COMPONENT REQUIREMENTS	: Laser linewidth : Polarisation stabilisation : Sub-systems
SYSTEMS EXPERIMENTS	: Example : World status
APPLICATIONS	: High bitrate long-haul : Wideband distribution

POTENTIAL OF COHERENT SYSTEMS



Also applications in inter-satellite communications, Sensors and Fibre measurements (OTDR)

ADVANTAGES OF COHERENT TRANSMISSION

IMPROVED SENSITIVITY

: Conversion gain from photomixing

: Choice of more efficient modulation schemes (PSK)

: Minimum received power proportional to B.W rather than $(B.W)^{3/2}$ c.f PinFet

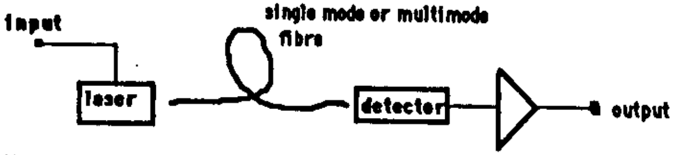
INHERENT SELECTIVITY

: Electrical filter bandwidths translated to optical frequencies

: Efficient use of available optical bandwidth. (up to 50.000GHz in silica low loss windows)

: Optical noise filtering (amplified spont. in TWA)

DIRECT DETECTION SYSTEM



- linewidth typically > 500GHz
- intensity modulation by direct modulation of injection current
- photocurrent proportional to received optical power
- Noise determined by detector in the case of APD or by following electronic amplifiers in case of P.I.N diode.

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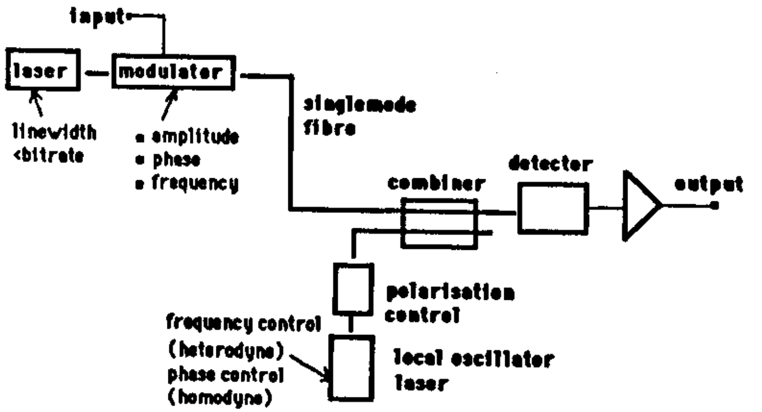

- Signal photocurrent is proportional to :- signal field X local oscillator field.
- Noise dominated by shot noise produced by strong local oscillator

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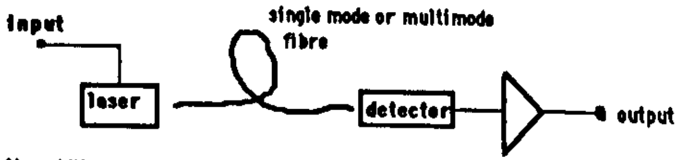

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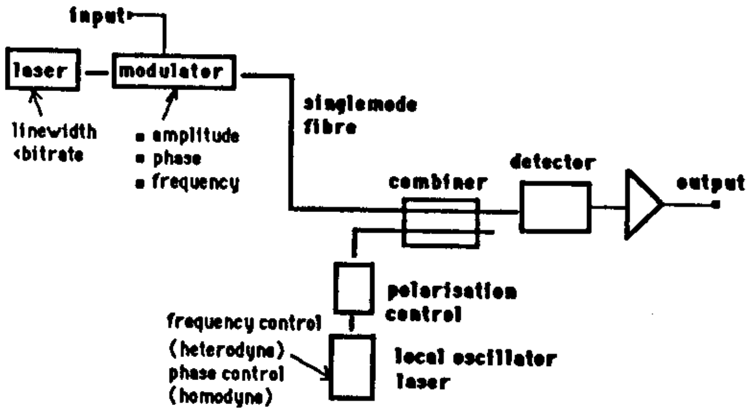

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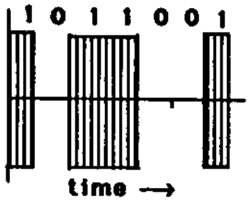
DIGITAL OPTICAL MODULATION

AMPLITUDE SHIFT KEYING (ASK)

amplitude modulation :-

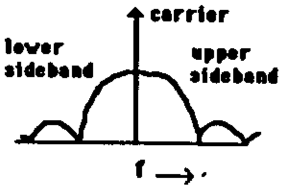
$$E_s = E_c \cos W_c t \; (1 + m(t))$$

for binary digital ; m(t)=0, 1



time ⟶

Envelope



optical spectrum

- HALF POWER WASTED IN CARRIER
- MEAN POWER = 1/2 PEAK POWER

PHASE SHIFT KEYING (PSK)

$$E_s = E_c \cos(W_c t + \phi_m(t))$$

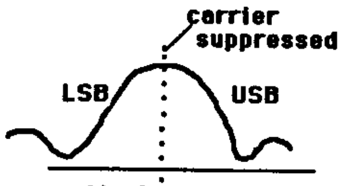
ideal binary PSK, ϕ (t) =0 for a 1, π for a 0

$\therefore E_{s1} = -E_{s0}$

CONSTANT ENVELOPE
(peak power =mean power)

CARRIER SUPPRESSED
(all energy in sidebands)

- 3dB better sensitivity
- Immunity to some non-linear effects i.e SBS.



optical spectrum

FREQUENCY SHIFT KEYING (FSK)

transmit '0' as f_1 and '1' as f_2

- CONSTANT ENVELOPE
- ASK SENSITIVITY FOR WIDE DEVIATION ($f_1 - f_2$>>bitrate)

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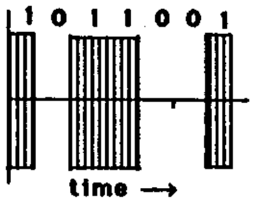

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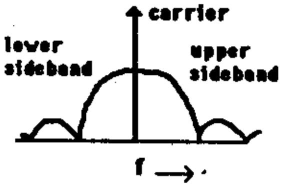

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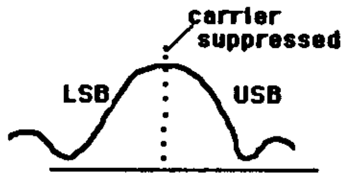

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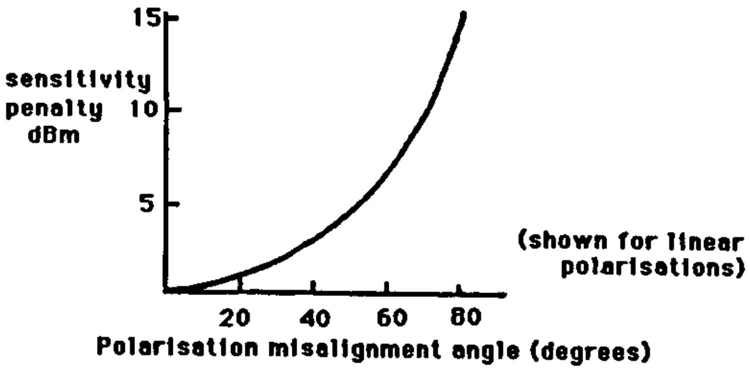
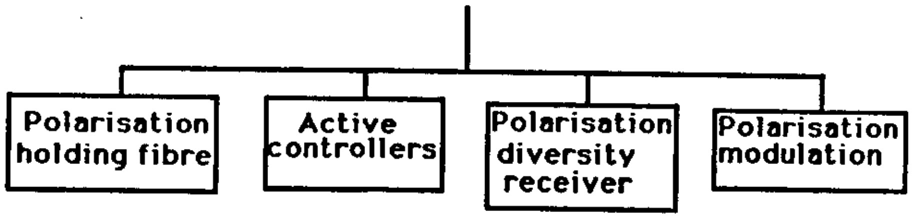
POLARISATION REQUIREMENTS

EFFECT OF POLARISATION MISALIGNMENT
ON RECEIVER SENSITIVITY



DEALING WITH POLARISATION CHANGES



Active control

- photoelastic (fibre squeezers) — Ulrich Appl.Phys lett.
- bulk electrooptic (Lithium Niobate) — Suematsu Electron.lett.
- integrated optic (Lithium Niobate) — Alferness IEEE.JQE
- magnetooptic (Faraday effect in Silica fibre) — Okoshi IOOC83

DEVELOPING TECHNIQUES WITH ENDLESS CONTROL RANGE IS NOW AN IMPORTANT TOPIC

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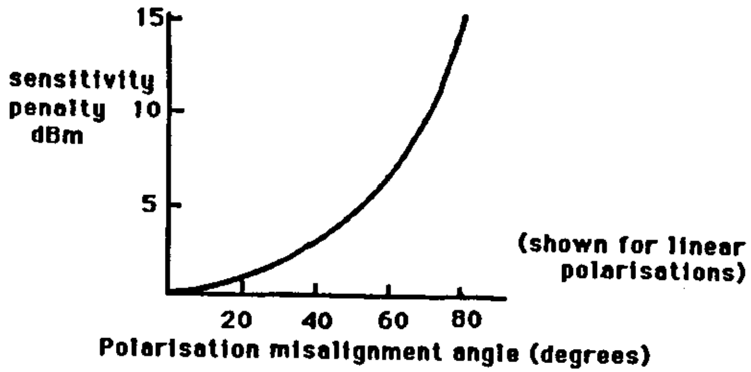

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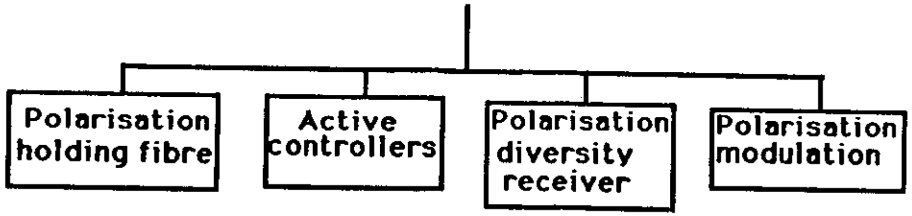

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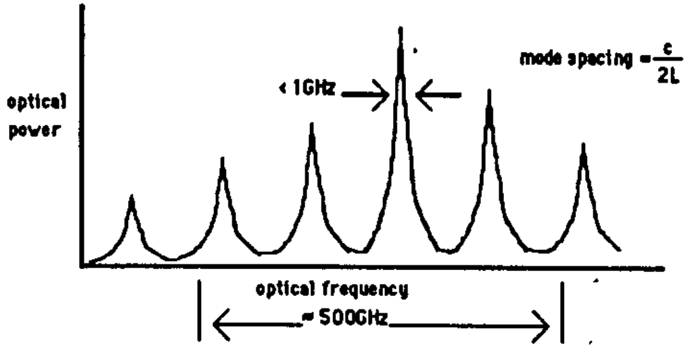
SPECTRUM OF FABRY-PEROT SEMICONDUCTOR LASER



SINGLEMODE SPECTRAL LINEWIDTH

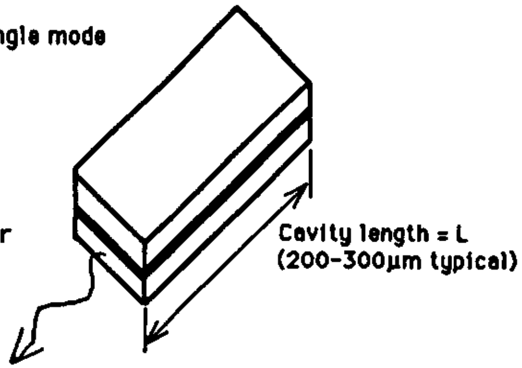
Linewidth of a single mode

$$\Delta f = \frac{K.\ S_p}{L^2\ P_e}$$

Sp=Spontaneous power

P_e = output power

$\Delta f \approx$ 10MHz-100MHz



INCREASING LENGTH SHOULD REDUCE SINGLEMODE LINEWIDTH ...BUT...REDUCED MODE SPACING INCREASES THE NUMBER OF MODES WITHIN MATERIAL GAIN SPECTRA

FOR RELIABLE SINGLEMODE OPERATION NOW REQUIRE A DISPERSIVE ELEMENT IN CAVITY OR COMPOUND CAVITIES.

c.f: DFB, DBR, External Grating Cavities, C 3 .

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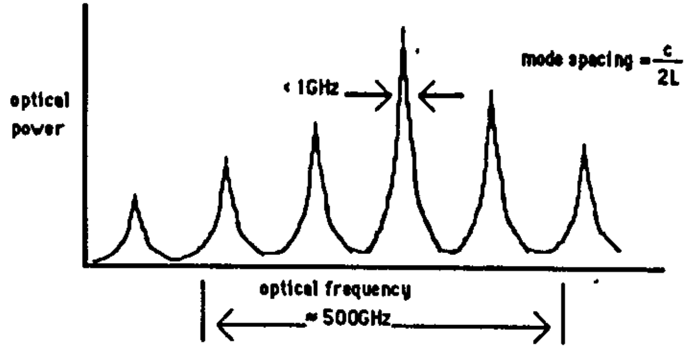

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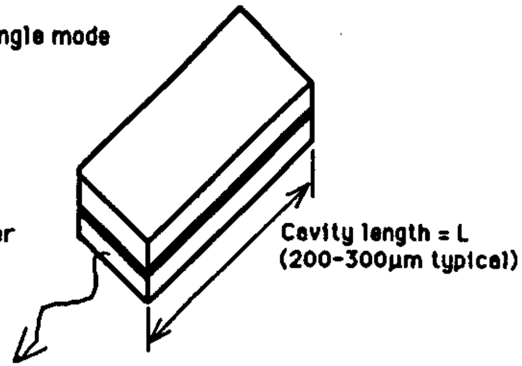

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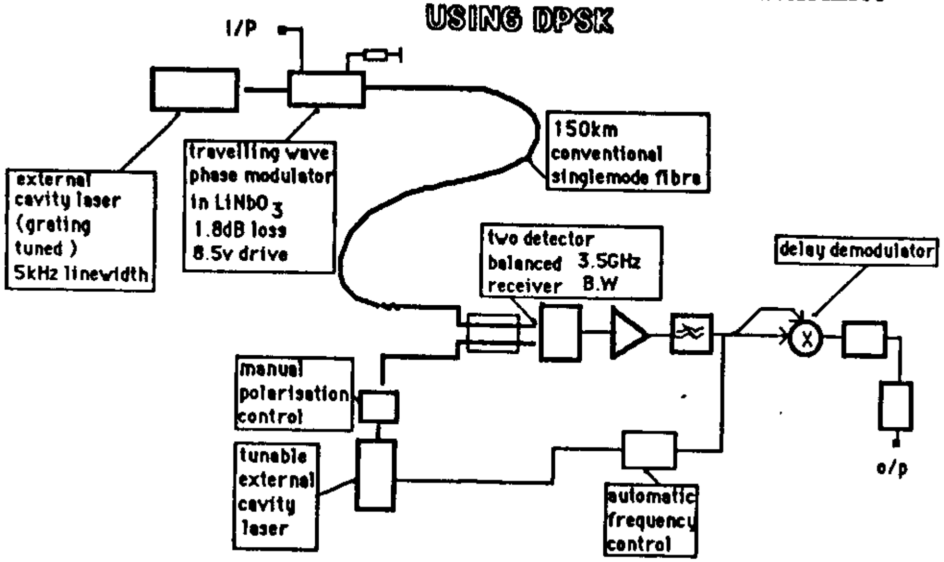

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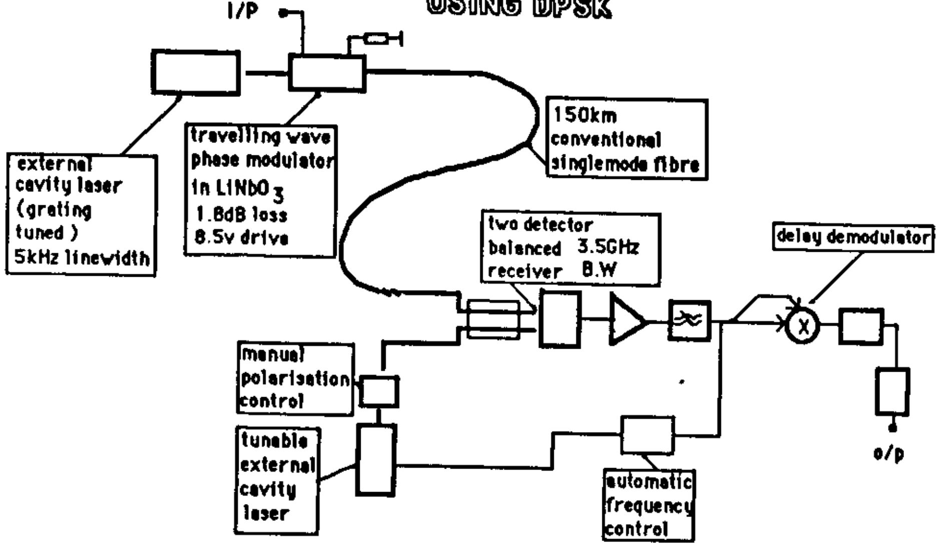

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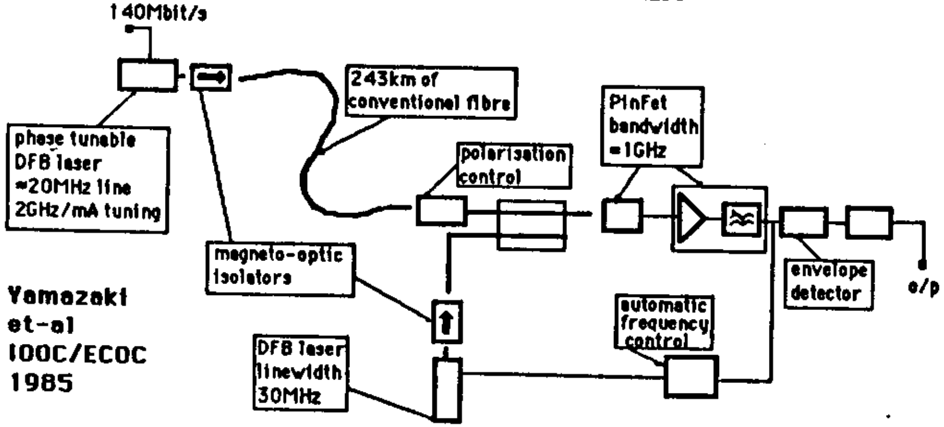

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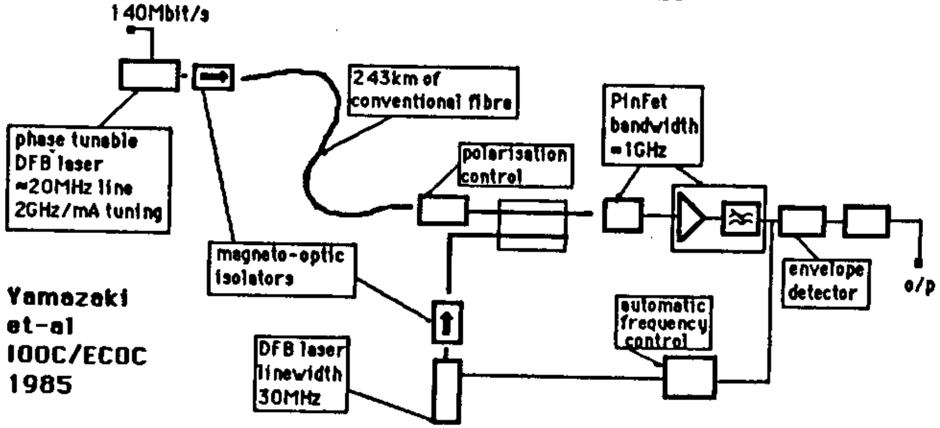

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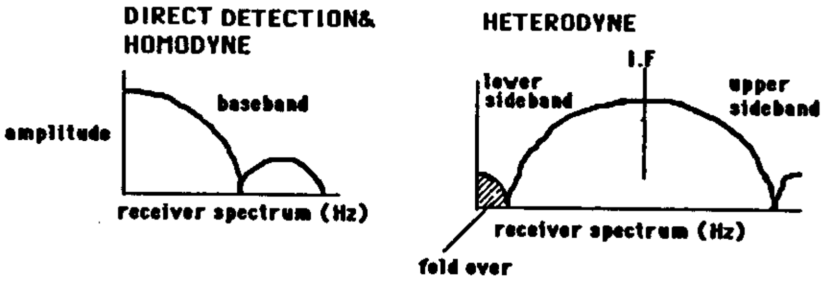
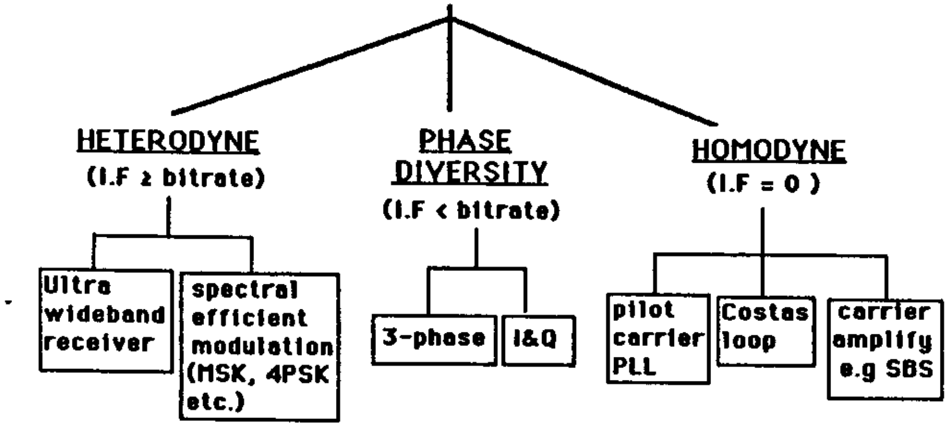
HIGH DATA RATE COHERENT TRANSMISSION

THE PROBLEM

Direct detection receivers require a receiver bandwidth of between 50%-100% of the clock rate <u>but</u> heterodyne receivers may require bandwidths of 200%-500% of the clock rate.



SOLUTIONS



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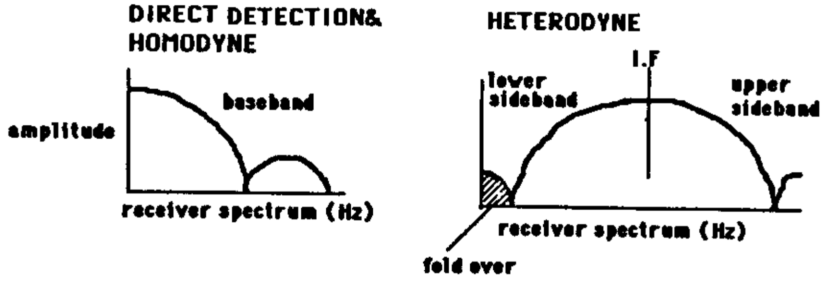

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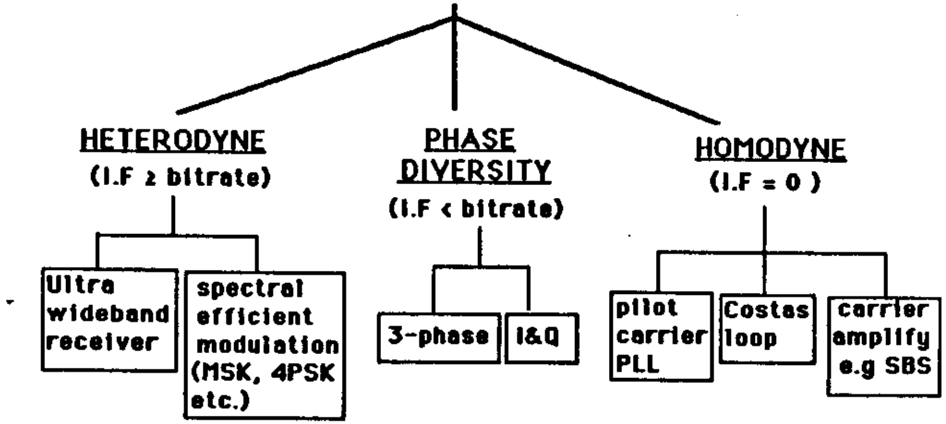
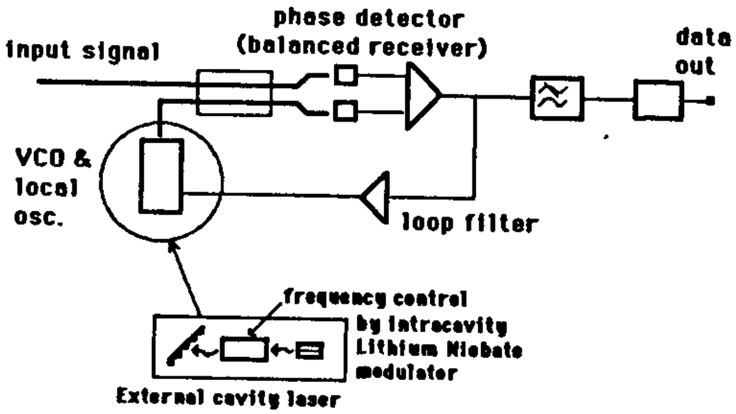


HOMODYNE DETECTION

Homodyne detection gives <u>3dB</u> better receiver sensitivity then heterodyne detection and requires less than <u>1/2</u> of the receiver bandwidth BUT would normally require a Phase locked loop.

OPTICAL PHASE LOCKED LOOP RECEIVER



HOMODYNE DETECTION: THE PROBLEMS

<u>PILOT CARRIER PHASED LOCK LOOP RECEIVER</u>

- Laser linewidth 0.05% to 0.1% of the data rate
  EXTERNAL CAVITY LASERS
- Local oscillator must have fast electrooptic tuning for wide PLL bandwidth
  INTRA-CAVITY MODULATORS
- d.c coupling in receiver leads to drift problems with sub-nanoWatt pilot carriers.
  SELF BALANCING RECEIVER
- Rayleigh backscatter from reflected local oscillator adds noise to low level pilot carrier
  SPECIAL TECHNIQUES REQUIRED
  (See Malyon et-al Electron. Lett, 421,1986.)

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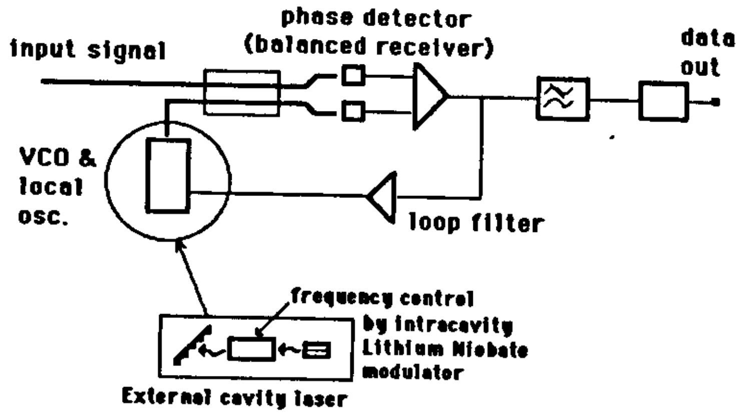

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