THE USE OF POLARISATION INTERLEAVE MULTIPLEXING TO REDUCE THE LEVEL OF CROSSTALK IN DWDM mm-RADIO SYSTEMS

William J. O'Brien MPhys.

MRes in Telecommunications student

University College London, Department of Electrical Engineering

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WHAT IS A mm-RADIO NETWORK?

It is a hybrid fibre radio (HFR) network

Fibre optics make up the core of the network
The last drop to the customer is provided by a wireless link

Availability of bandwidth at low GHz (1-10GHz) frequencies is highly restricted.

Considerably more bandwidth available at higher mm- frequencies.

We could use this bandwidth to provide high data rates to the customer where and when it is needed.

Flexibly and cheaply

WE WOULD THERFORE LIKE TO UTILISE THE mm-SECTION OF THE SPECTRUM

(20 - 100 GHz).

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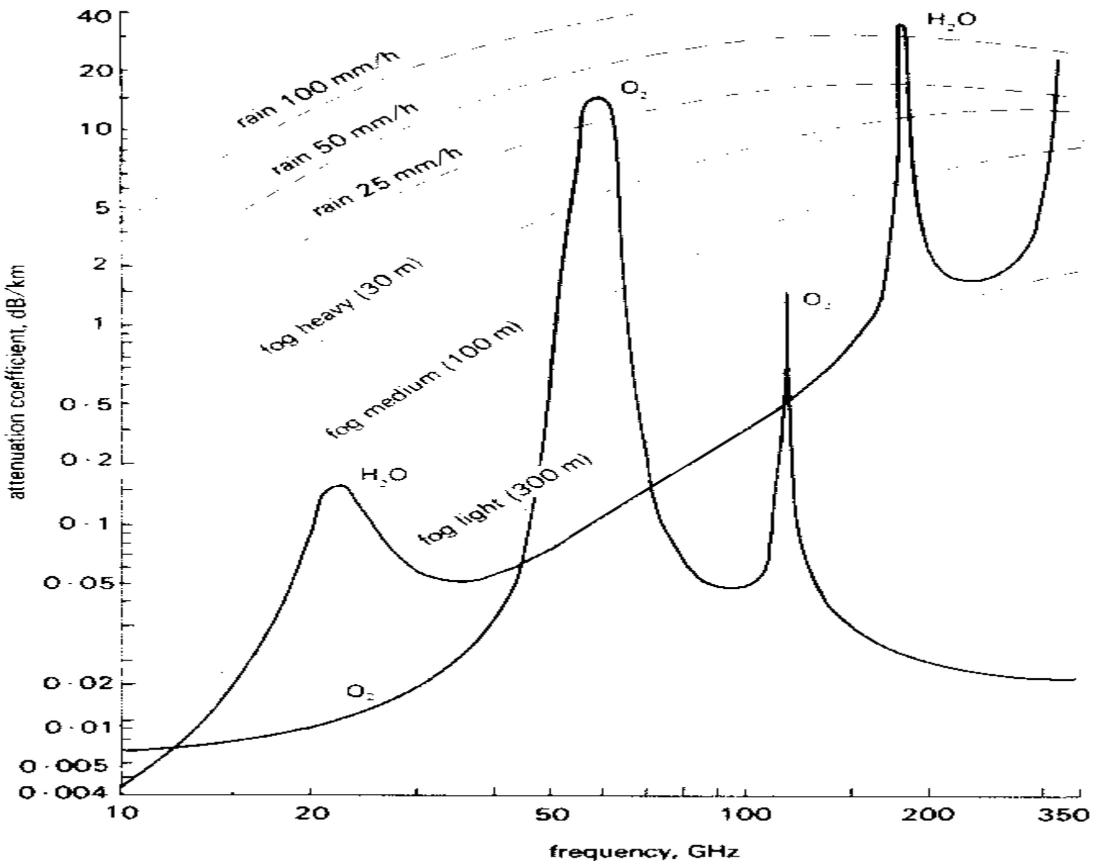
ATMOSPHERIC ATTENUATION CHARACTERISTICS AT mm-FREQUENCIES



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ATMOPHERIC ATTENUATION IS MUCH HIGHER AT mm-WAVELENGTHS THAN AT LOWER GHz FREQUENCIES.

A large concentration of base stations is required.

Each Base station might serve an area of only 50m in diameter (picocells).

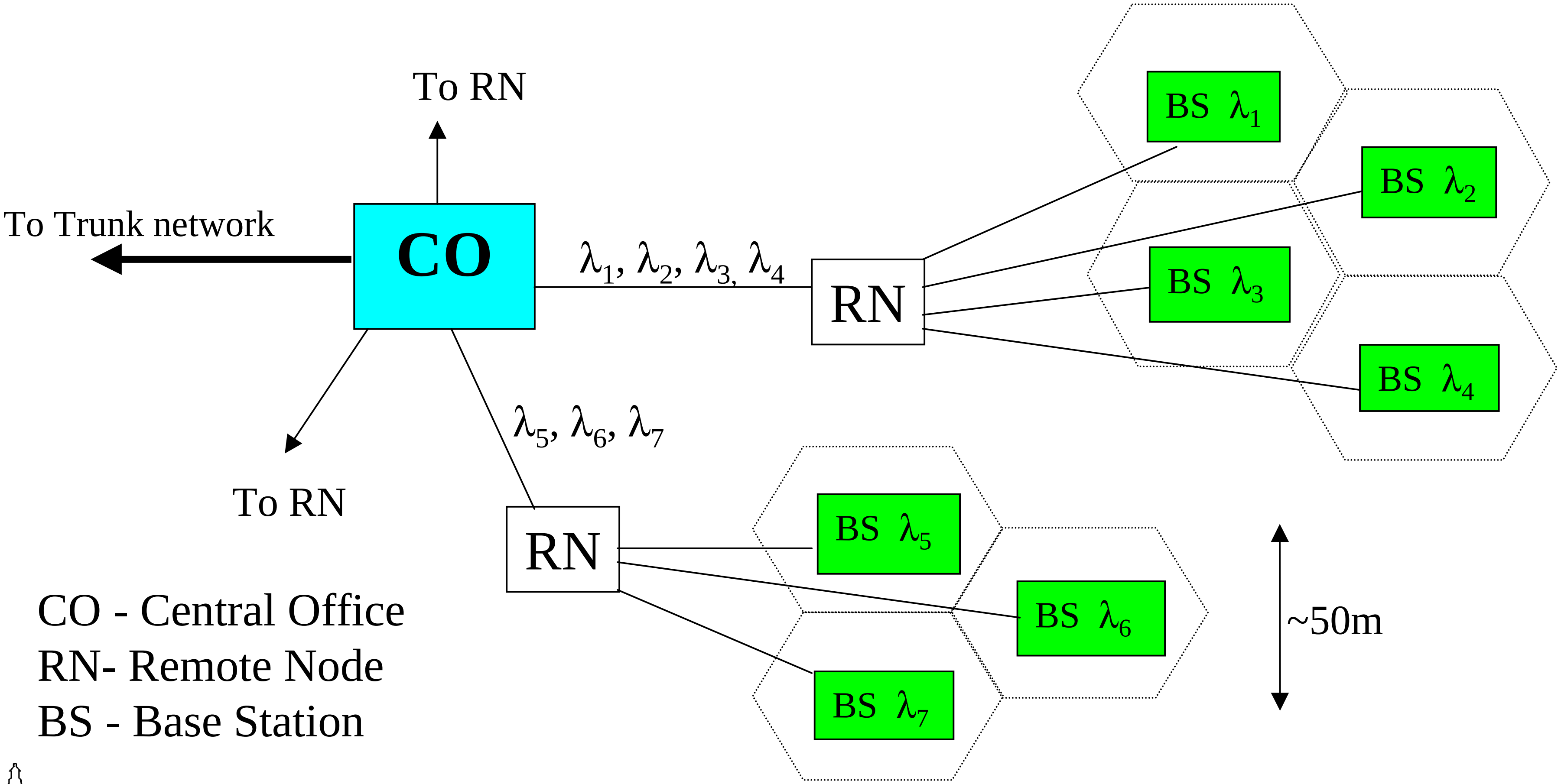
BASE STATIONS MUST BE

1- CHEAP TO BUILD AND RUN

2- SUPPORT BROADBAND DUPLEX DATA TRANSMISSION

3 - SMALL, FOR AESTHETIC REASONS

mm-RADIO NETWORK IN A STAR-TREE ARCHITECTURE



CO - Central Office
RN- Remote Node
BS - Base Station

Using DWDM makes best use of fibre capacity

POTENTIAL APPLICATIONS

Wireless Local Loop (WLL)

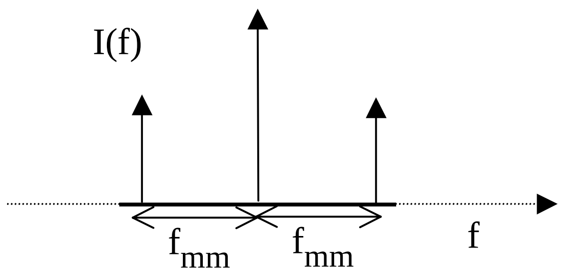
Wireless Local Area Networks (WLANS)

Mobile communications (beyond UMTS)

Intelligent Vehicle Highway systems (IVHS)

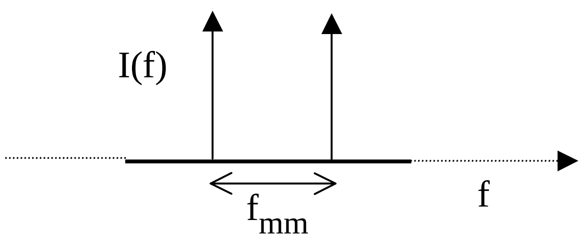
mm-WAVE MODULATION TECHNIQUES

3-term techniques



Conventional Double Sideband (DSB) modulation

2-term techniques



Double Sideband Suppressed Carrier (DSBSC)
Single Sideband (SSB)
1 laser 4f method
2 laser techniques
using Optical Phase Locked Loop (OPLL)
or an Optical Frequency Locked Loop (OFLL)

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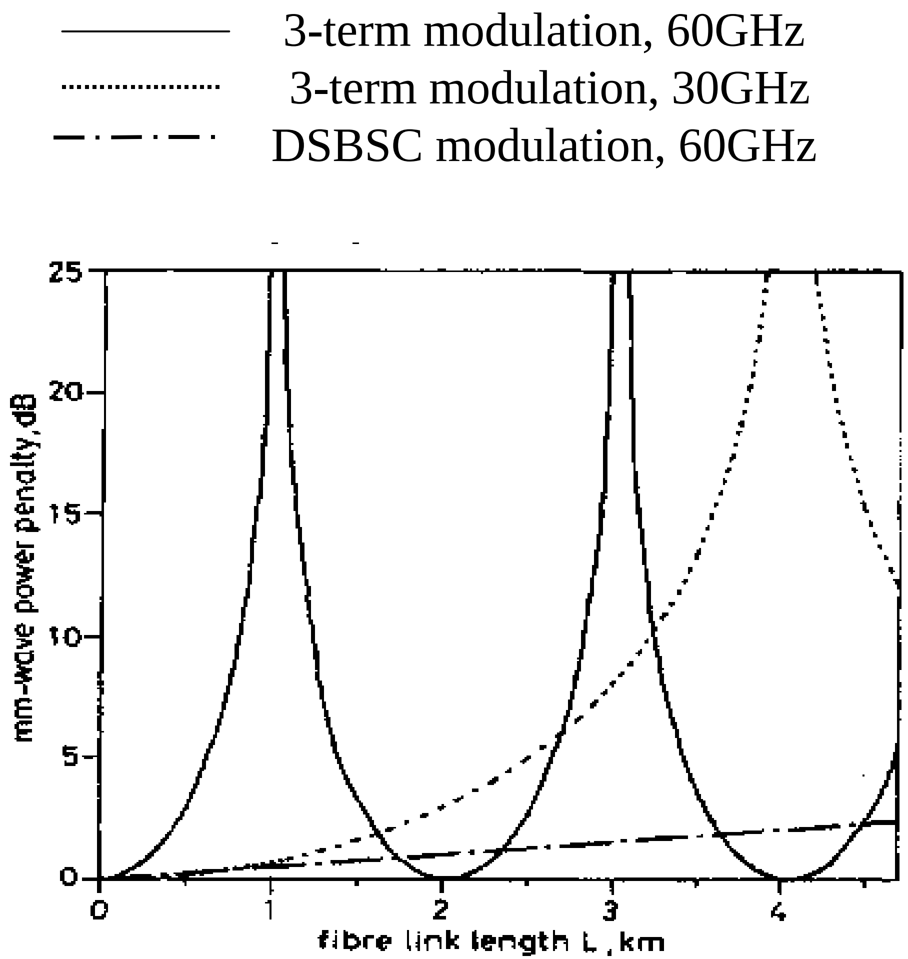
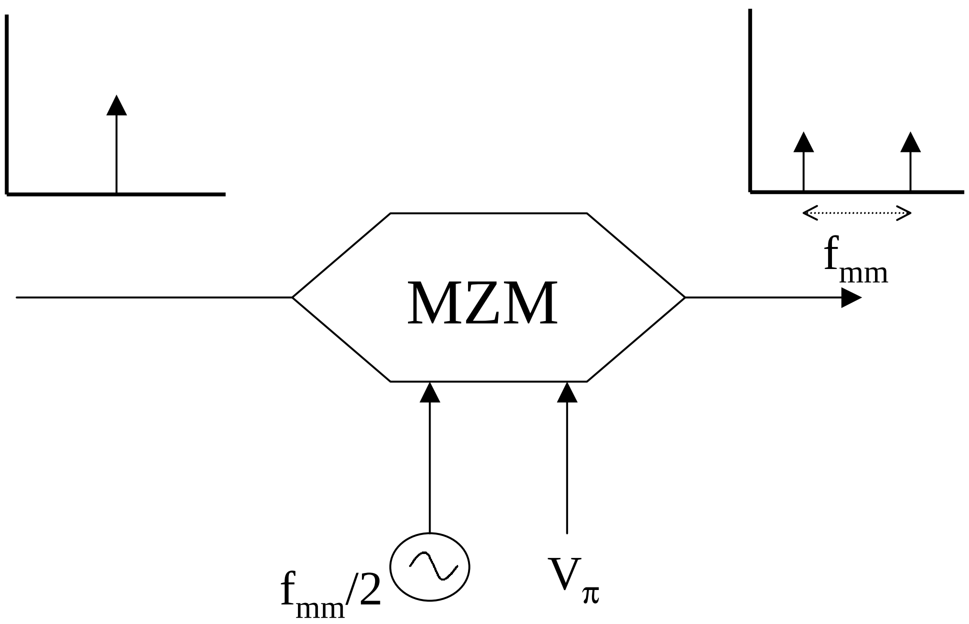
POWER PENALTY VS. FIBRE LENGTH FOR 3 DIFFERENT MODULATION FORMATS



OPTICAL DOUBLE SIDEBAND SUPPRESSED CARRIER



By biasing a Mach-Zehnder Modulator (MZM) at V_π, the point of minimum optical transmission, and driving it at half the required mm-frequency, f_{mm}, we can suppress the carrier and produce a pair of sidebands separated by f_{mm}.

HIGHER-ORDER SIDEBANDS

As well as the two principal sidebands, DSBSC produces weaker higher-order sidebands

$$I(f) = \frac{E_0^{\ 2}}{8}\left\{J_0\left(\alpha\frac{\pi}{2}\right)\cos\left(\varepsilon\frac{\pi}{2}\right)\right\}^2 \delta(f - f_{DFB}) +$$

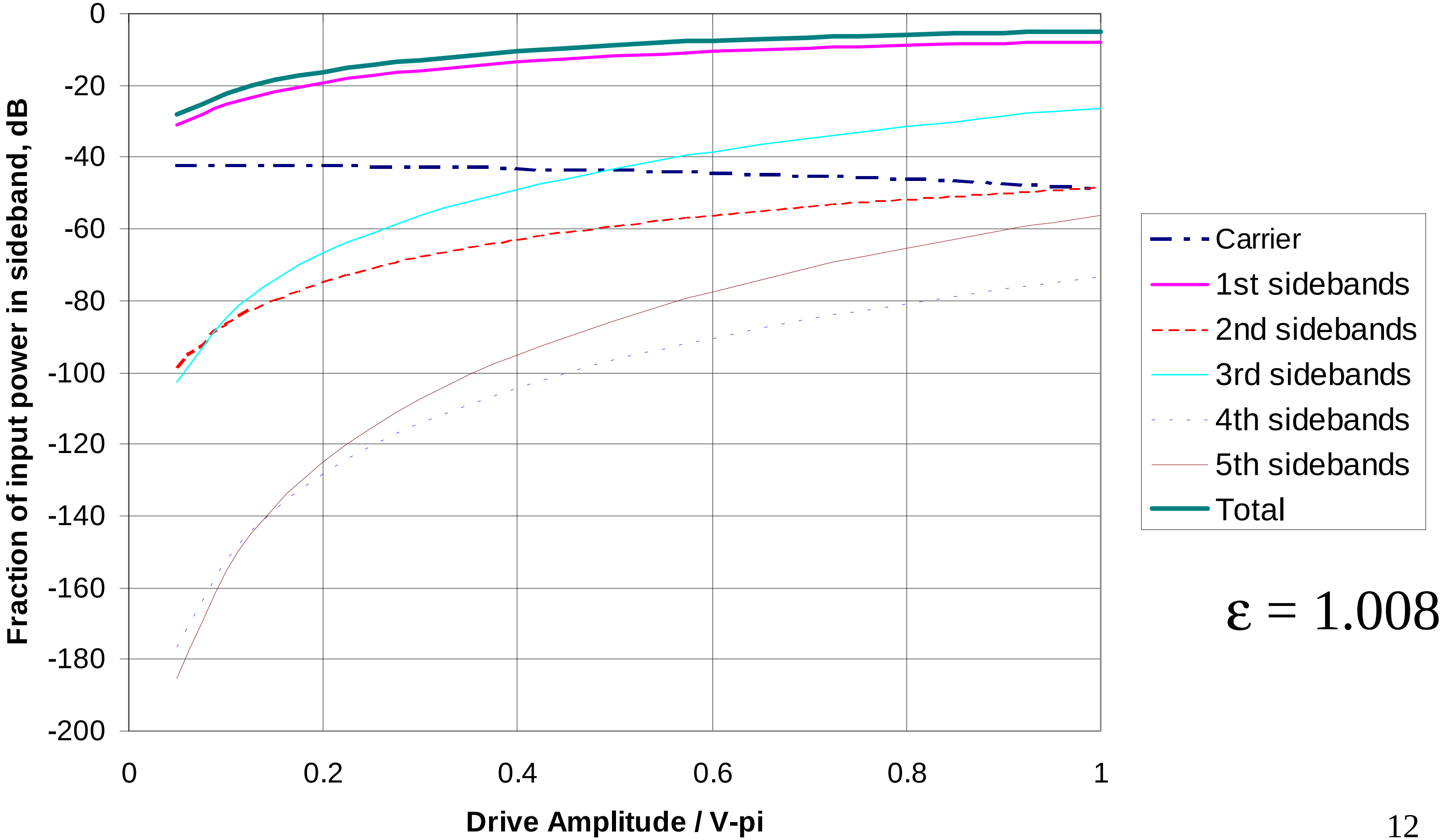
$$\sum_{n=-\infty, n\neq 0}^{n=\infty} \frac{E_0^{\ 2}}{2}\left\{J_n\left(\alpha\frac{\pi}{2}\right)\cos\left((\varepsilon + n)\frac{\pi}{2}\right)\right\}^2 \delta\left(f - (f_{DFB} + nf_{mm})\right)$$

α = drive amplitude voltage / V_π ε = bias voltage / V_π

Principal sidebands are where n = 1 or -1.
Other odd-numbered sidebands are weaker
All even-numbered = 0 if ε = 1.

POWER IN SIDEBANDS

Power in higher order sidebands increases with increasing the drive amplitude voltage



$\varepsilon = 1.008$

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THE ORIGIN OF THE CROSSTALK

The transmission function of an arrayed waveguide demultiplexer is Gaussian,

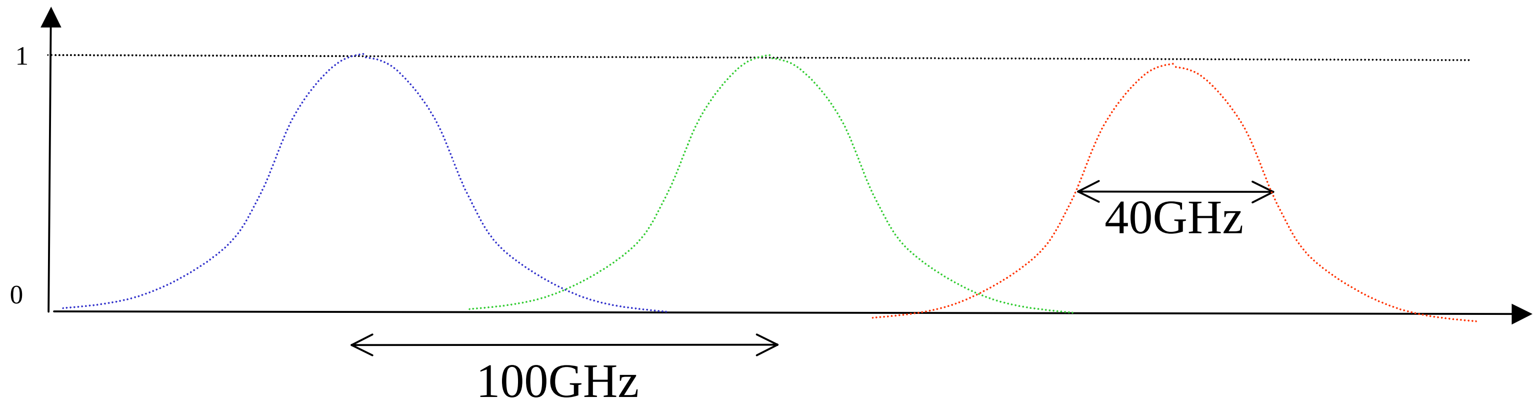
$$T(f) = \exp\left\{-\left(\frac{d(f - f_c)}{S\Delta f}\right)^2\right\}$$

with a FWHM of 30-40 GHz

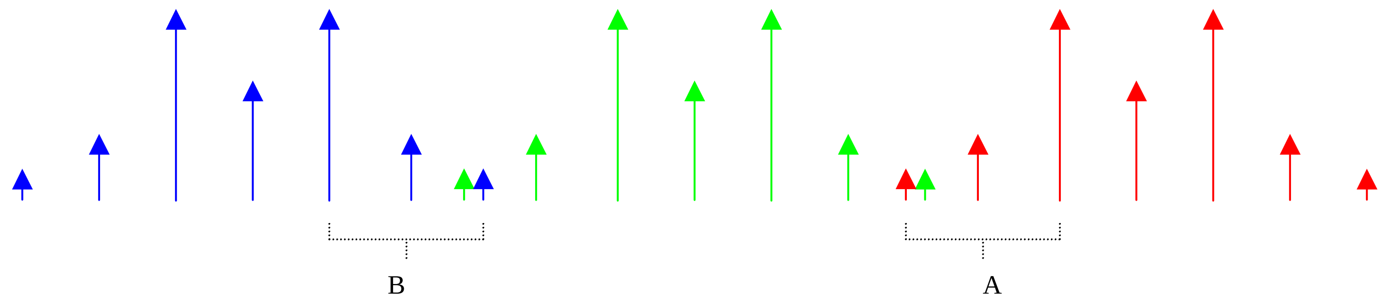
Aim is to use channel spacing of 100GHz, or less.

Those unwanted higher-order terms produce a small signal in the wrong channel i.e. CROSSTALK

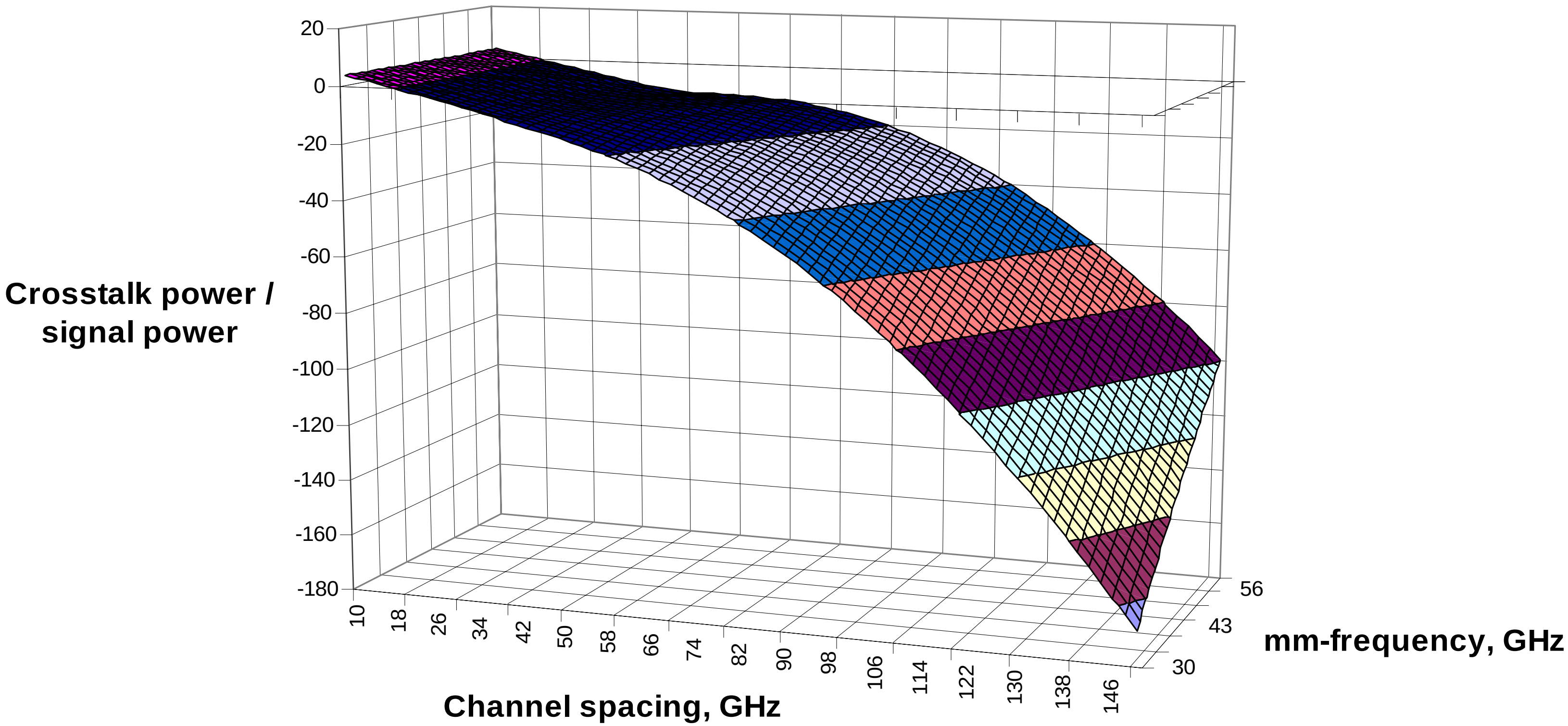
Channel filter functions



Pairs of tones that are responsible for crosstalk

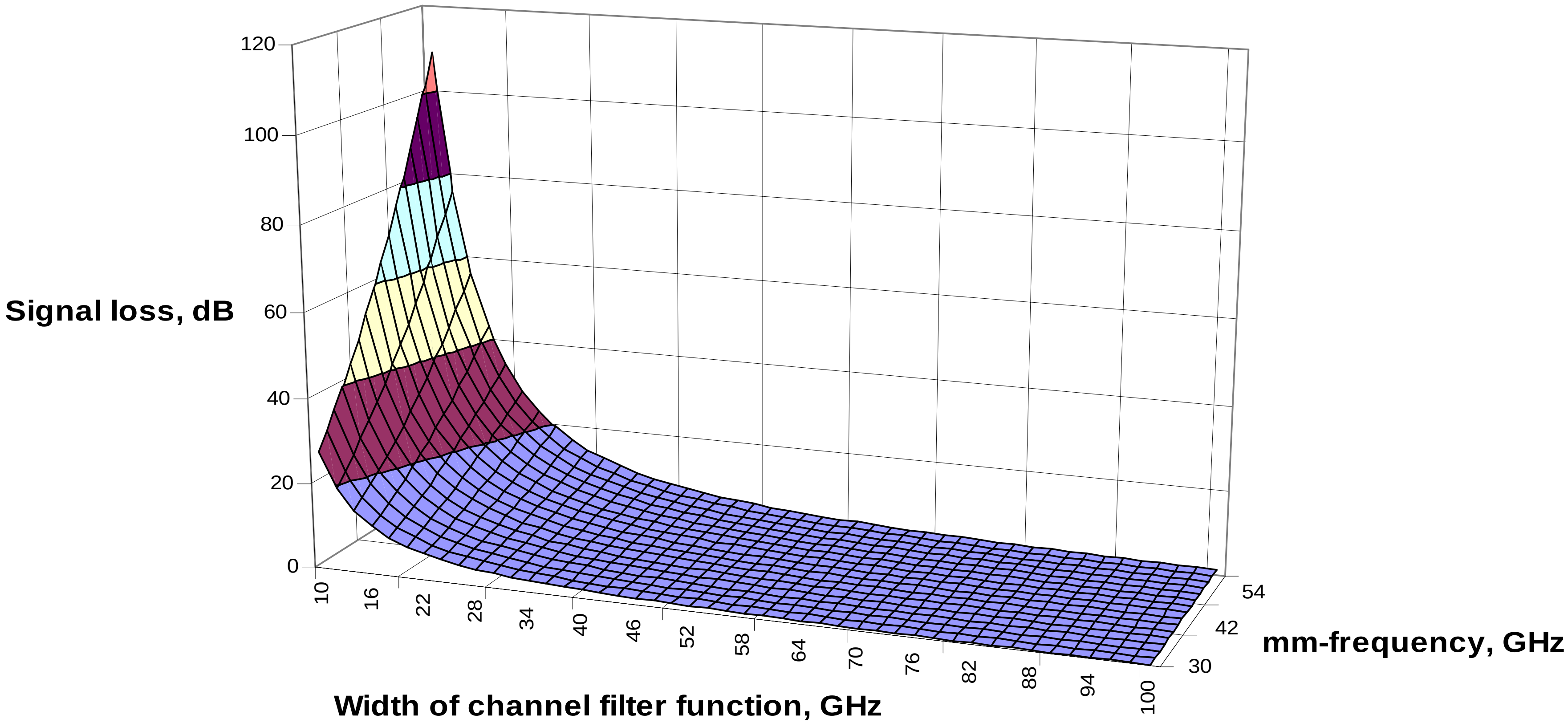


CROSSTALK TO SIGNAL POWER RATIO VS. CHANNEL SPACING AND mm-FREQUENCY



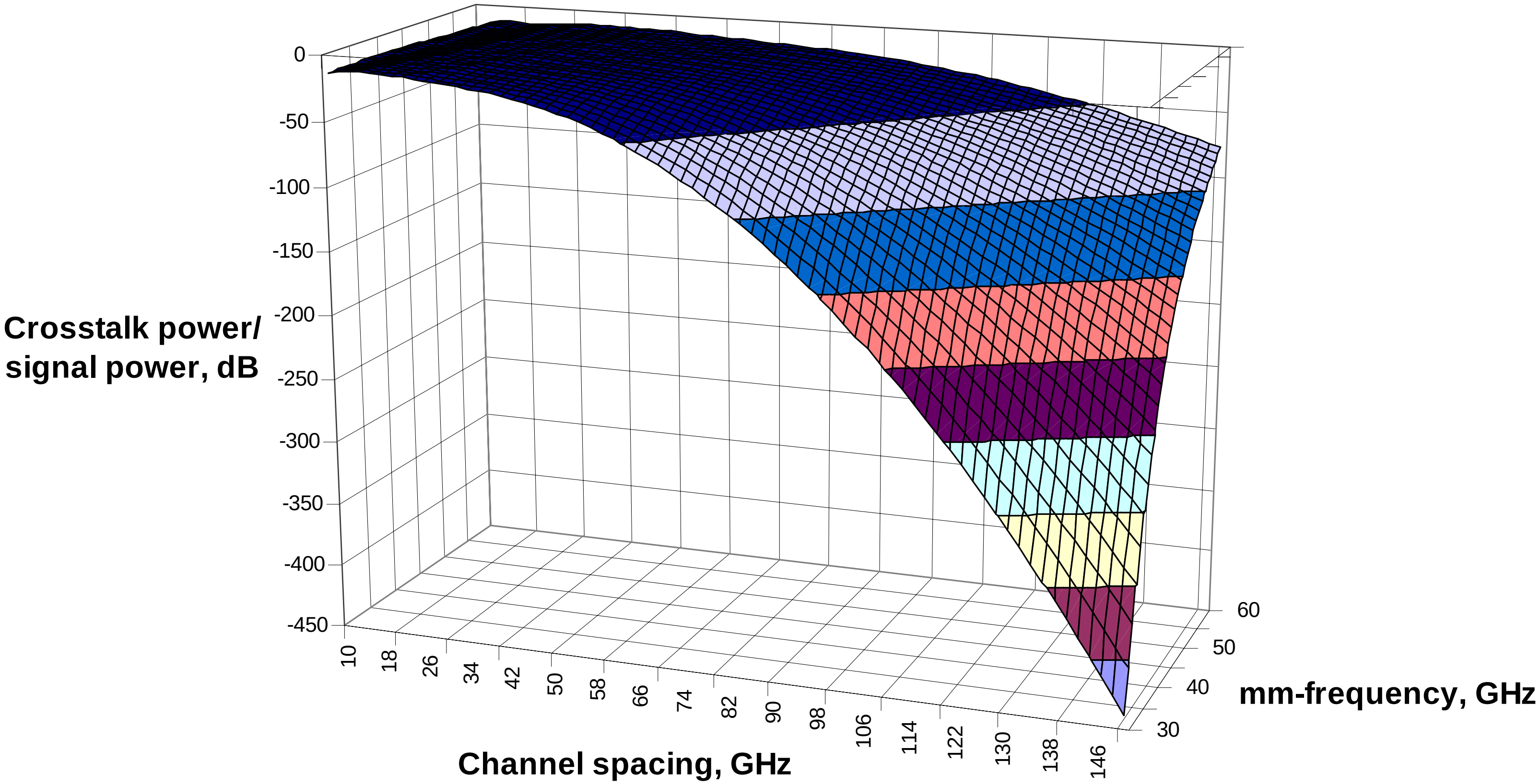
Width of Gaussian channel filter function = 40GHz

SIGNAL LOSS VS. CHANNEL SPACING AND mm-FREQUENCY



BOTH SIGNAL LOSS AND CROSSTALK ARE BIGGER PROBLEMS AT HIGHER FREQUENCIES.

CROSSTALK TO SIGNAL POWER RATIO WHEN SIGNAL LOSS IS HELD AT 7dB



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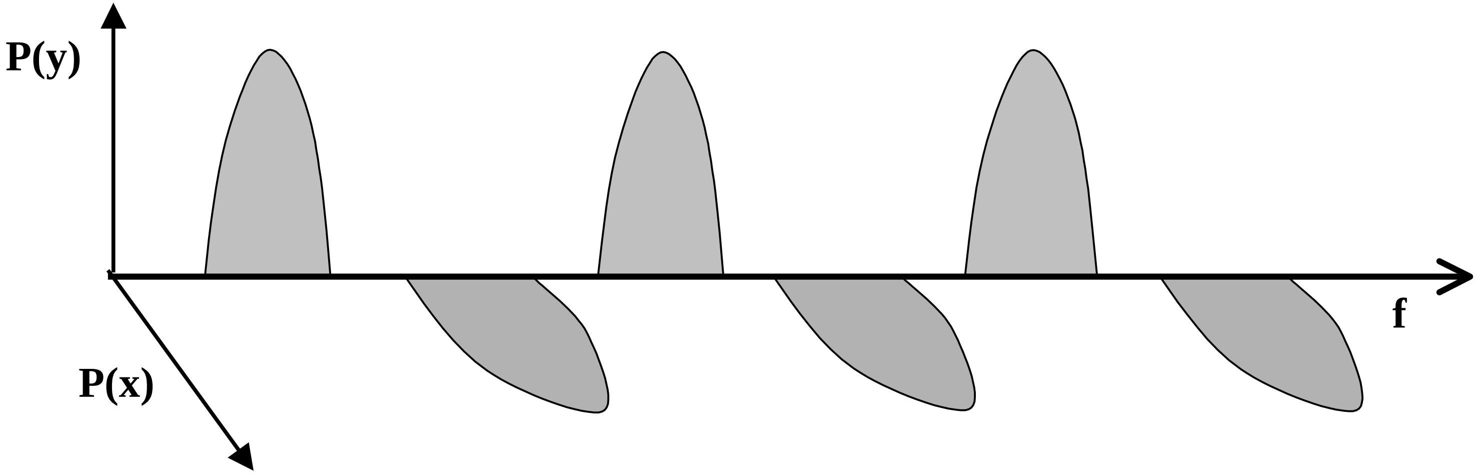
POLARISATION INTERLEAVE MULTIPLEXING



This is scheme where adjacent channels are launched at orthogonal polarisations

This can significantly reduce crosstalk.

DEPOLARISATION

Random variations in birefringence in fibres causes depolarisation

The degree of polarisation, $$DOP(z) = \frac{I_{max}(z) - I_{min}(z)}{I_{max}(z) + I_{min}(z)}$$

Decays exponentially with distance $$DOP(z) = DOP(0)\, e^{-z/d},$$

d is the decorrelation length, or depolarisation length.

Standard Fibre	d = 1m - 1km
Polarisation preserving fibre	d = 100km - 10^4km

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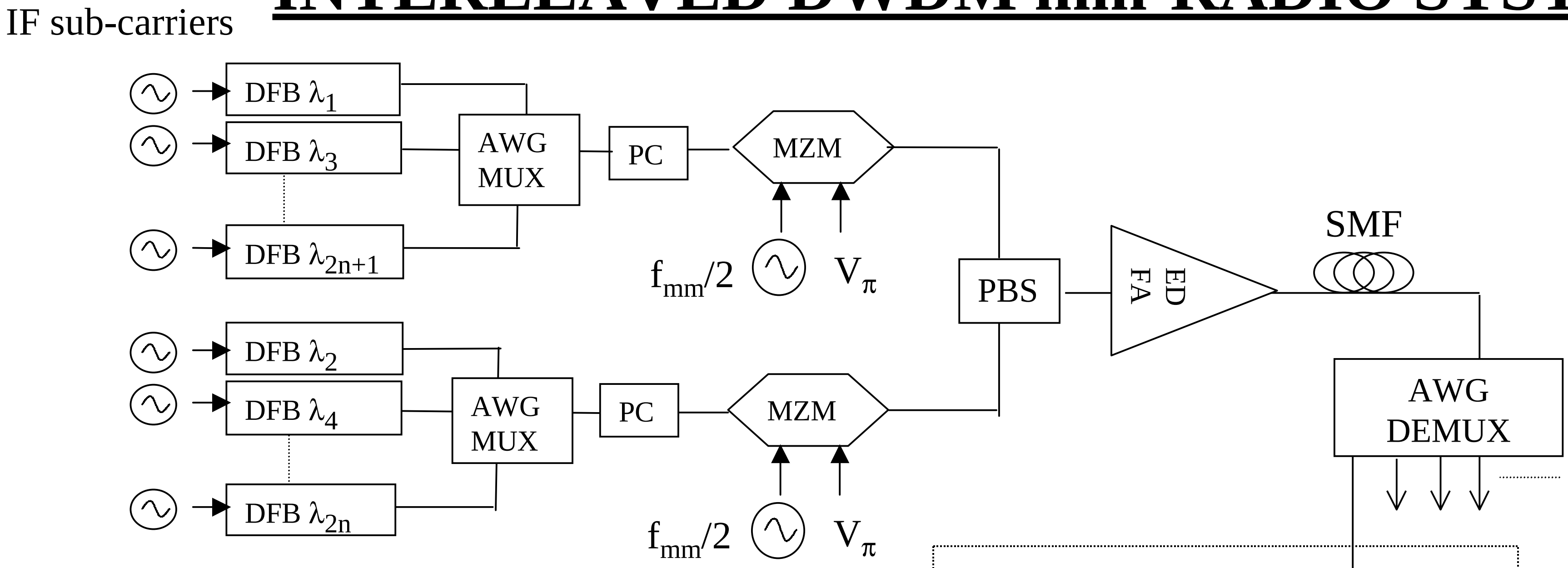
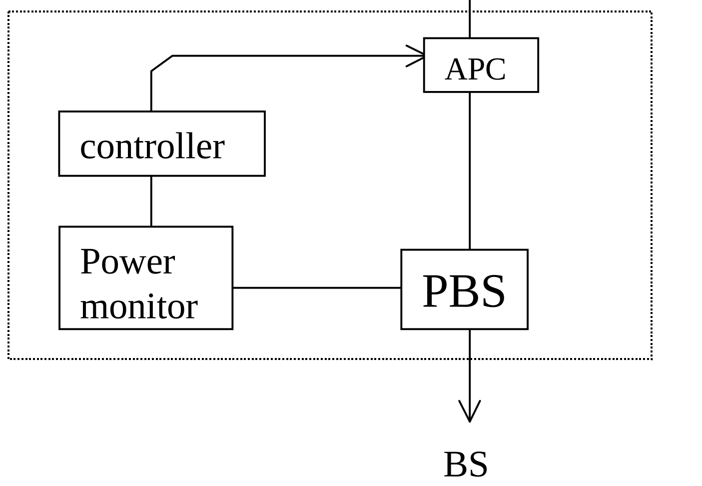
A SET-UP FOR A POLARISATION INTERLEAVED DWDM mm-RADIO SYSTEM





DFB - Distributed Feedback Laser
PC - Polarisation Controller
PBS - Polarisation Beam Splitter
MZM - Mach-Zehnder Modulator
AWG MUX – Arrayed Waveguide Multiplexer
AWG DEMUX – Arrayed Waveguide Demultiplexer
EDFA – Erbium Doped Fibre amplifier
SMF - Standard Monomode Fibre
APC - Automatic Polarisation Controller

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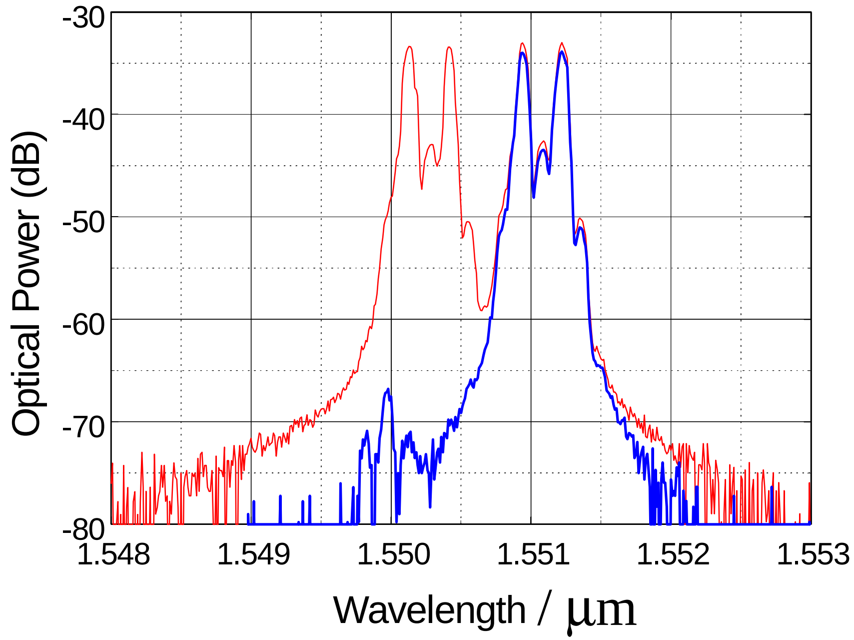
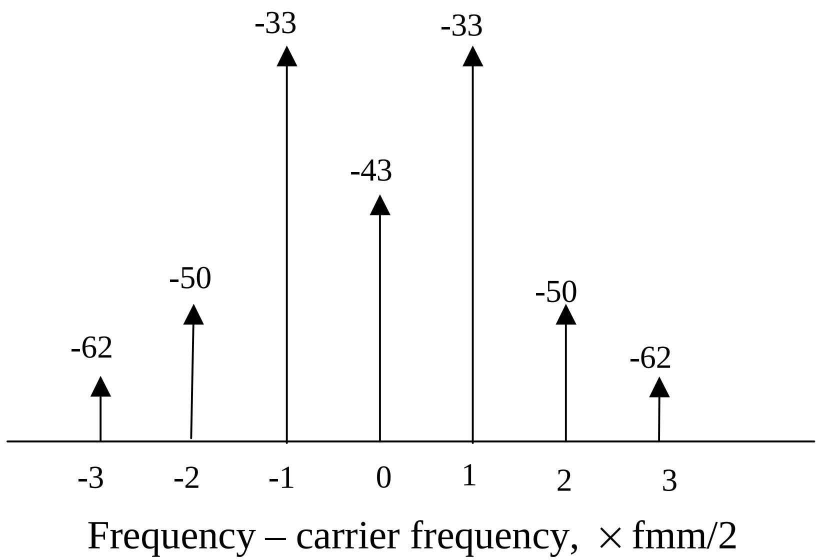
ESTIMATED SIDEBAND POWERS





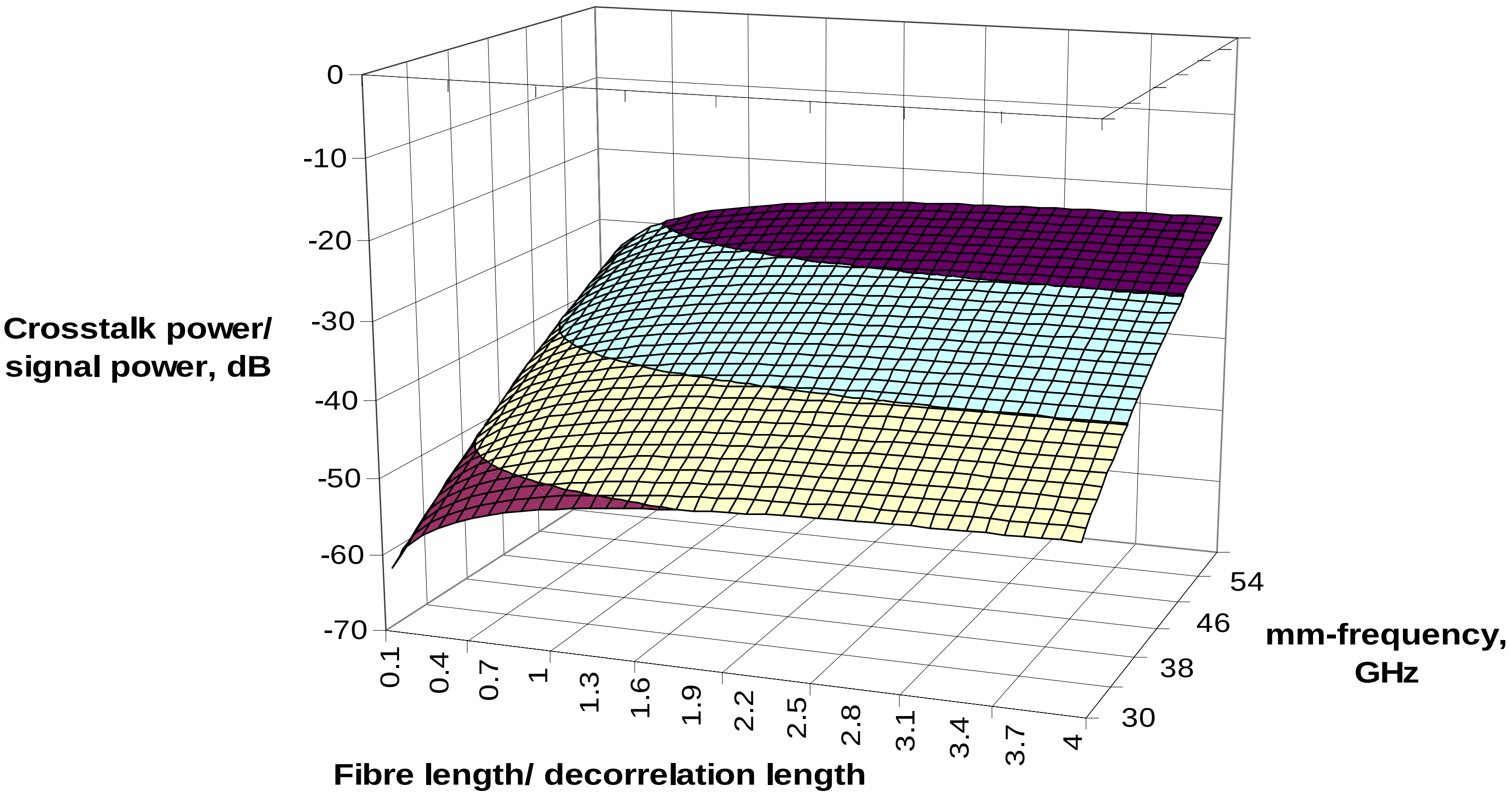
Red line - spectrum of two channels

Blue line - spectrum of one channel as selected by fibre Bragg grating.

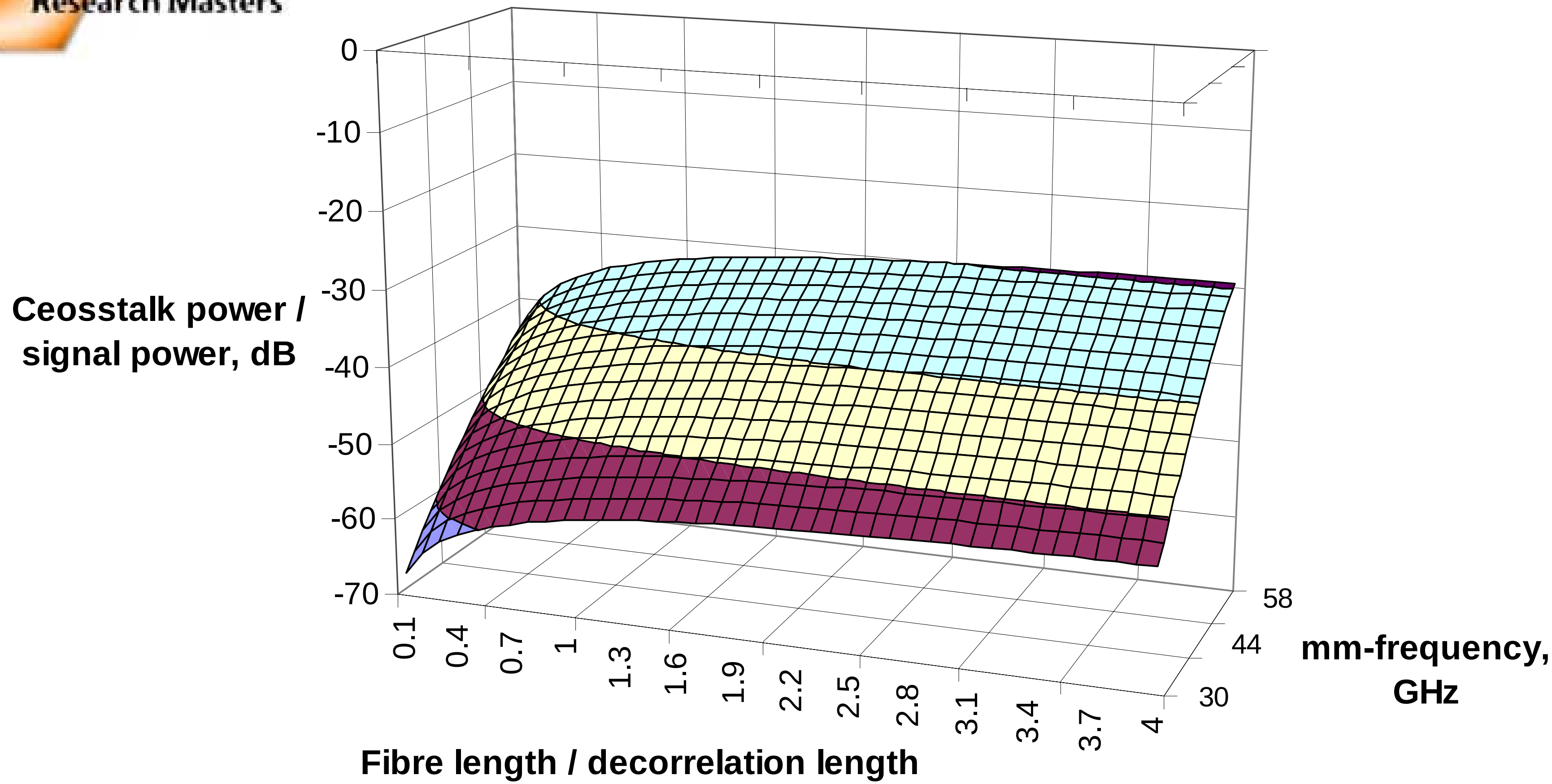
Powers in each sideband as estimated from OSA scan.

The power of each component in dB is relative to input power.

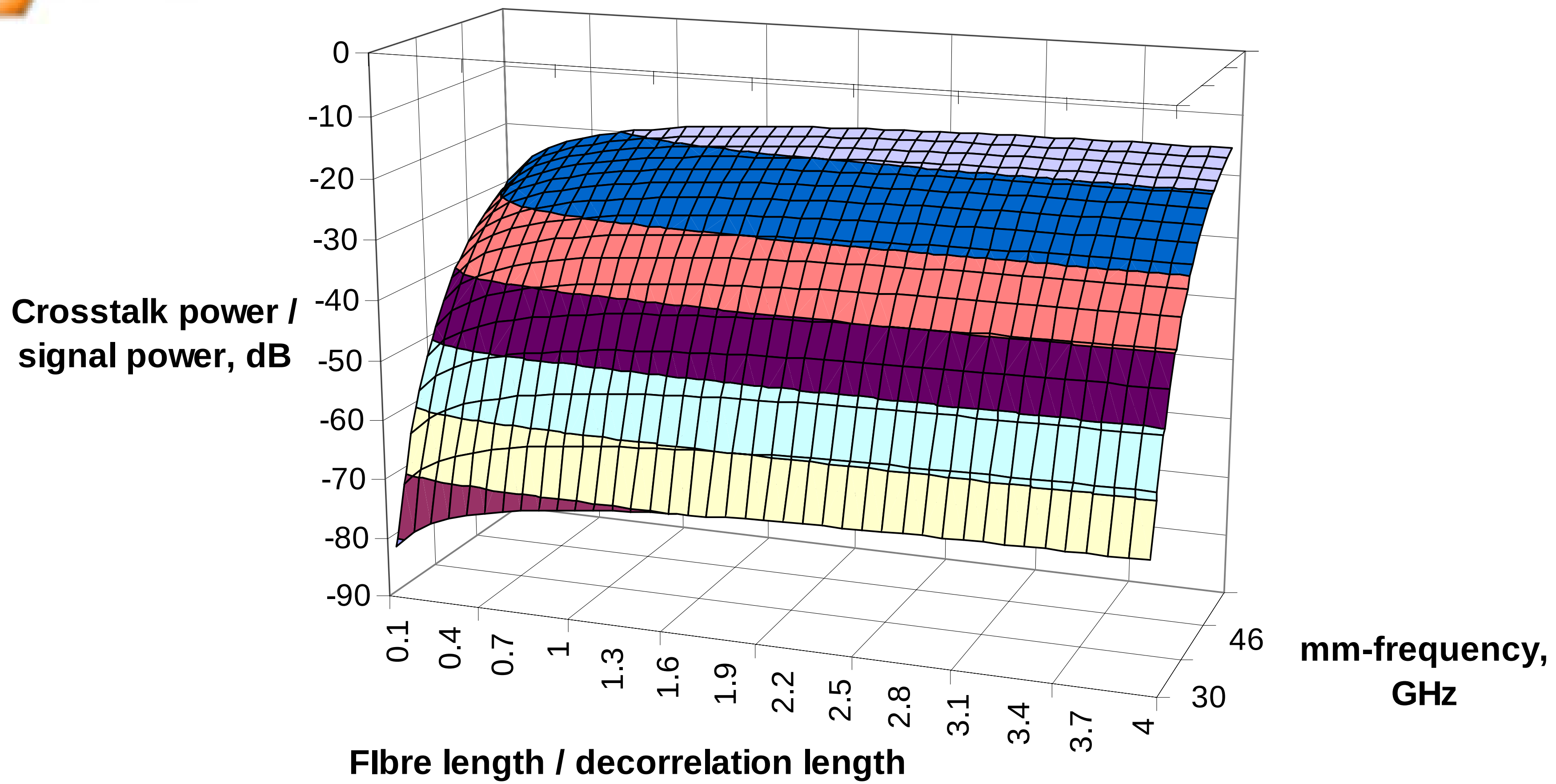
CROSSTALK WHEN POLARISATION INTERLEAVE MULTIPLEXING IS EMPLOYED



Channel spacing = 100GHz
Width of channel filter function = 40GHz
Sideband powers estimated from figure



Channel spacing = 100GHz
Width of channel filter function = 40GHz
Drive amplitude voltage = 0.3Vπ
r.m.s of bias voltage from Vπ = 0.008Vπ



Channel spacing = 100GHz
Signal loss held at 3dB
Sideband powers estimated from figure

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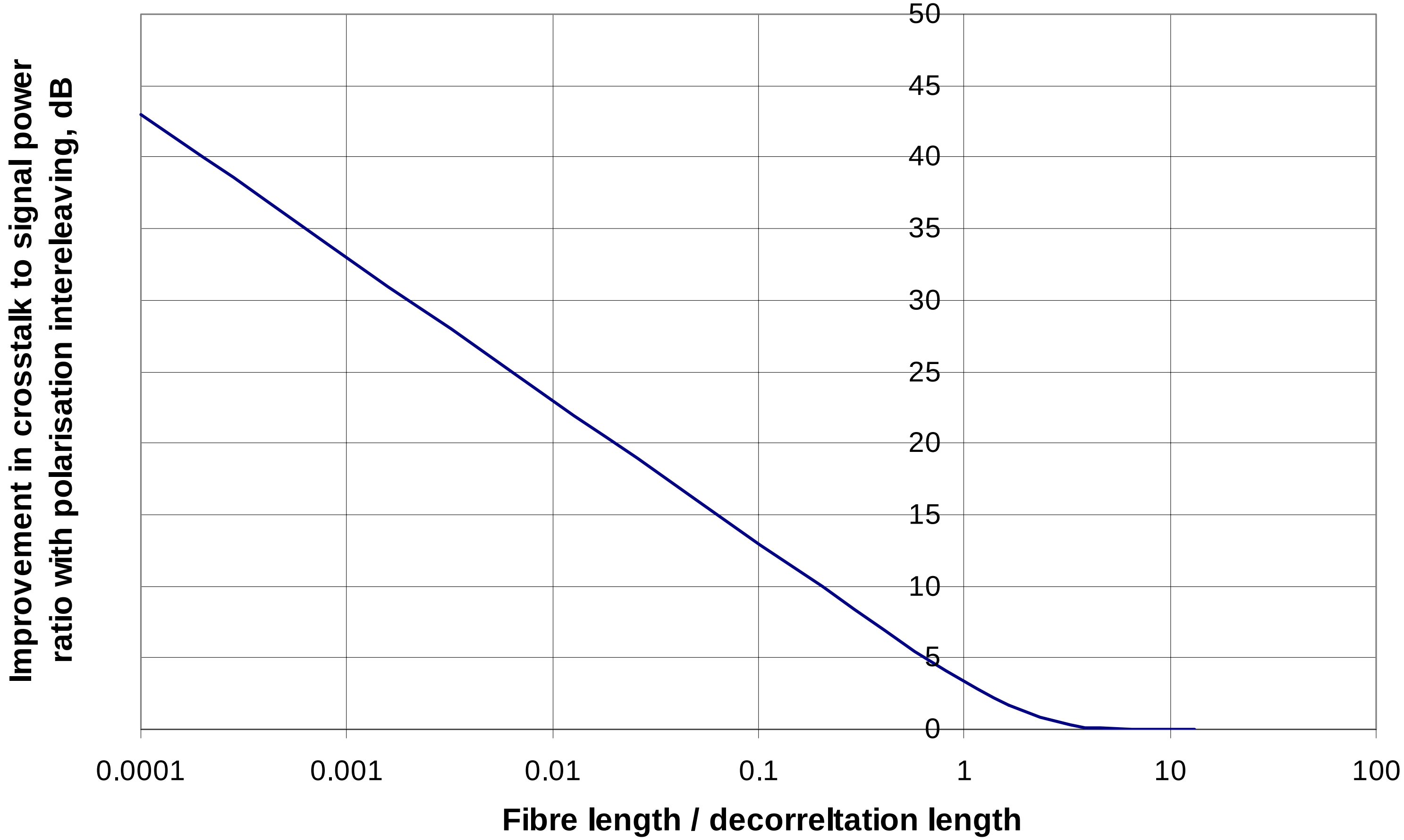
IMPROVEMENT IN CROSSTALK TO SIGNAL RATIO WHEN POLARISATION INTERLEAVING IS USED



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