JNM 2001

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FUTUROSCOPE - POITIERS

IRCOM

Journée Thématique

mardi 15 mai 2001

U.F.R. des Sciences - SP2MI (site du Futuroscope)

LES MICROONDES ET L'OPTIQUE DANS LES APPLICATIONS CIVILES ÉMERGENTES

❼

Microwave components technology for broadband wireless and high speed optical communications

(A.P.S. KHANNA - Agilent Technologies Santa Clara - USA)

Microwave Components Technology for Broadband Wireless and high speed optical communications

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Agenda

- Broadband and High-Speed Introduction
- Broadband Wireless - High Speed
- Optical Communications - High Speed
- Components and Modules Challenges
- Future Direction

Broadband and High Speed

- Need for Speed
- Technologies in play:
  - Fiber: high demand business, WAN, backbone Rings
  - Point to Point Radios: large customers, backbone
  - Point to Multipoint Radios: high and low density urban
  - Free-space Optics: short distances high speed
  - DSL: small customers, residential
  - Cable Modems: residential
  - Satellites: low density everywhere
- Wired vs. Wireless

High Speed Wireless Options Comparison >100Mb/s

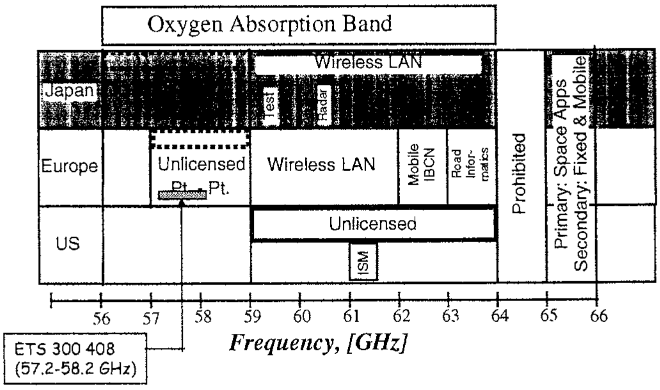
Medium	Speeds Available	Range	Cost per link	Issues
Free Space Optics	2.5 Gb/s 10 Gb/s	350- 1000 meters	$25K	Fog, Rain, Bldg. Sway
59-64 GHz	**622 Mb/s**	**300- 500 meters**	**$20K**	**Unlicensed band**
23, 26, 38 GHz	155 Mb/s	2 miles	$40K – 60K	Complexity, Cost
5.8 GHz	100 Mb/s 420 Mb/s	2 miles	$25K – 40K	Unlicensed

Bands for High Speed Wireless Access

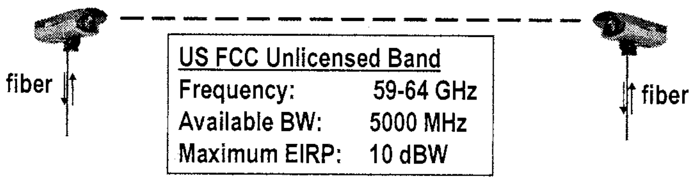
Frequency	Bandwidth	Description
5 - 6 GHz	100 MHz	ISM, UNII
21 to 23 GHz	Various	US, Europe, Asia
24.5 to 29.5 GHz	Various	Europe /Asia
27.5 to 31.3 GHz	1150 MHz	LMDS/LMCS
38.6 to 40 GHz	Various	US, Europe
40.5 to 43.5 GHz		MVDS/MWS Europe

International Spectrum Allocations

................*Present and Proposed*



60 GHz Radio Link



US FCC Unlicensed Band

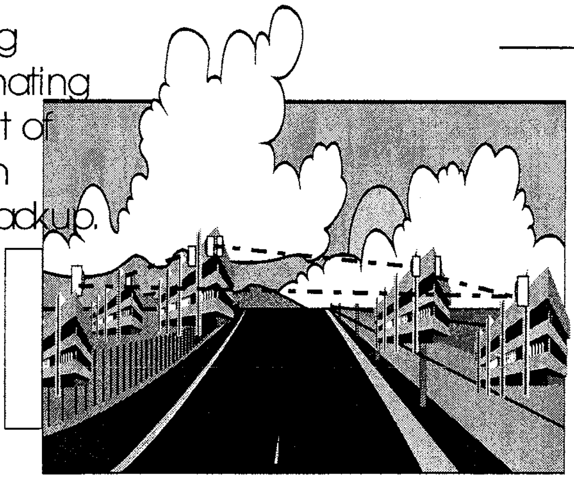
Frequency: 59-64 GHz
Available BW: 5000 MHz
Maximum EIRP: 10 dBW

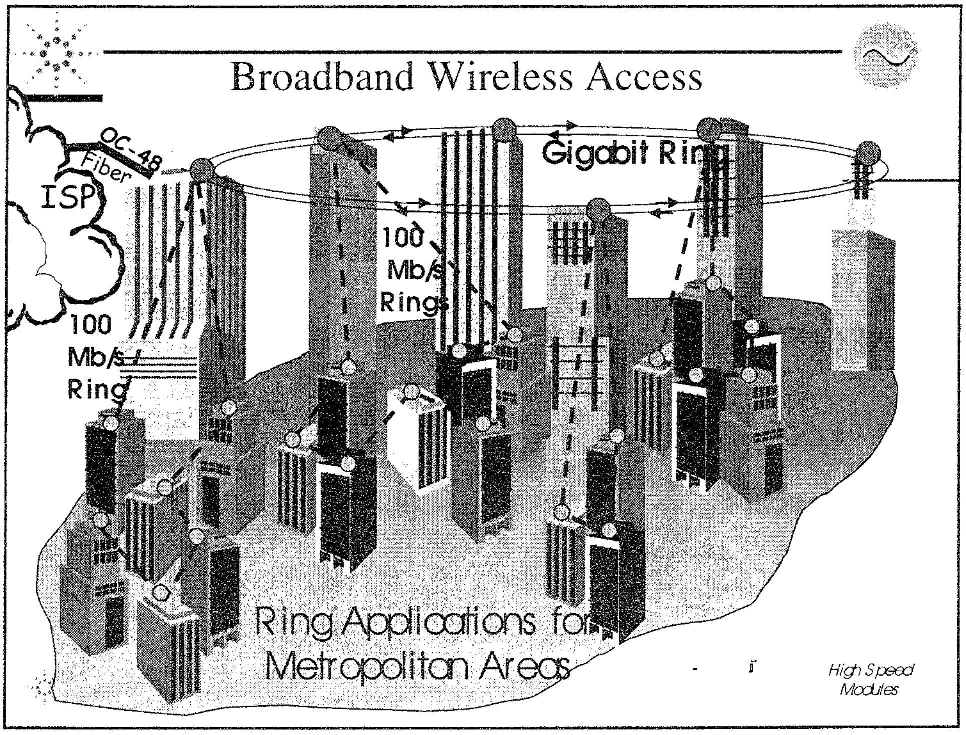
Potential Applications

- ☐ Campus Wireless LAN Extender
- ☐ Broadband Wireless Access

Campus Wireless LAN Extender

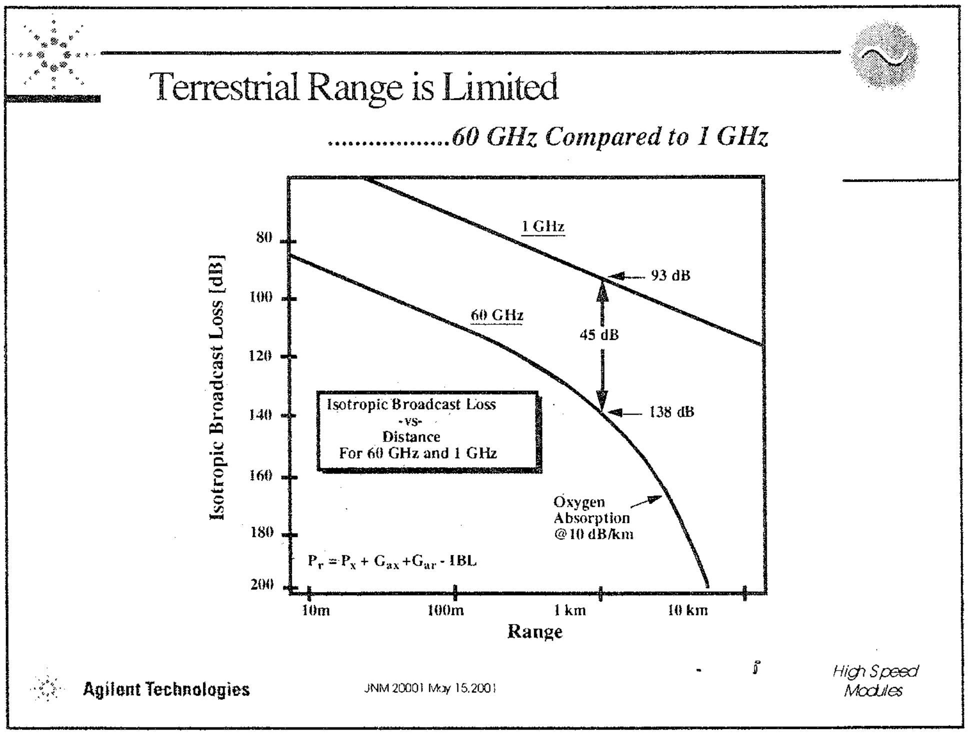
Ideal for crossing obstacles, eliminating the wait and cost of trenching and an excellent fiber backup.





Broadband Wireless Access

High Speed Modules



Terrestrial Range is Limited

..................60 GHz Compared to 1 GHz

$P_r = P_x + G_{ax} + G_{ar} - IBL$

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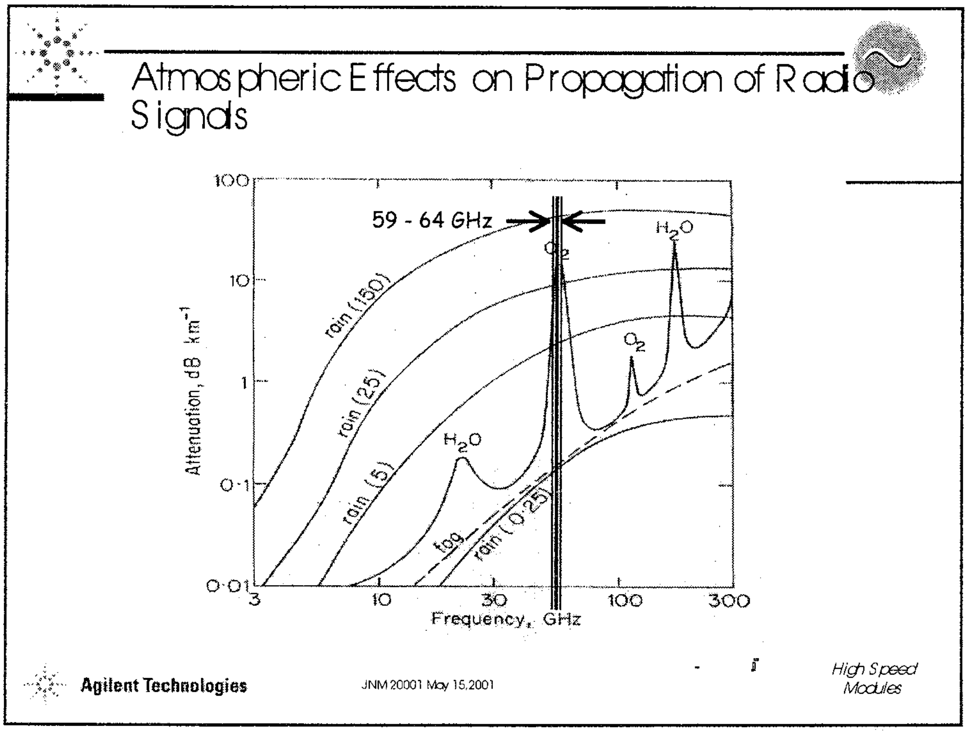
High Speed Modules



Atmospheric Effects on Propagation of Radio Signals

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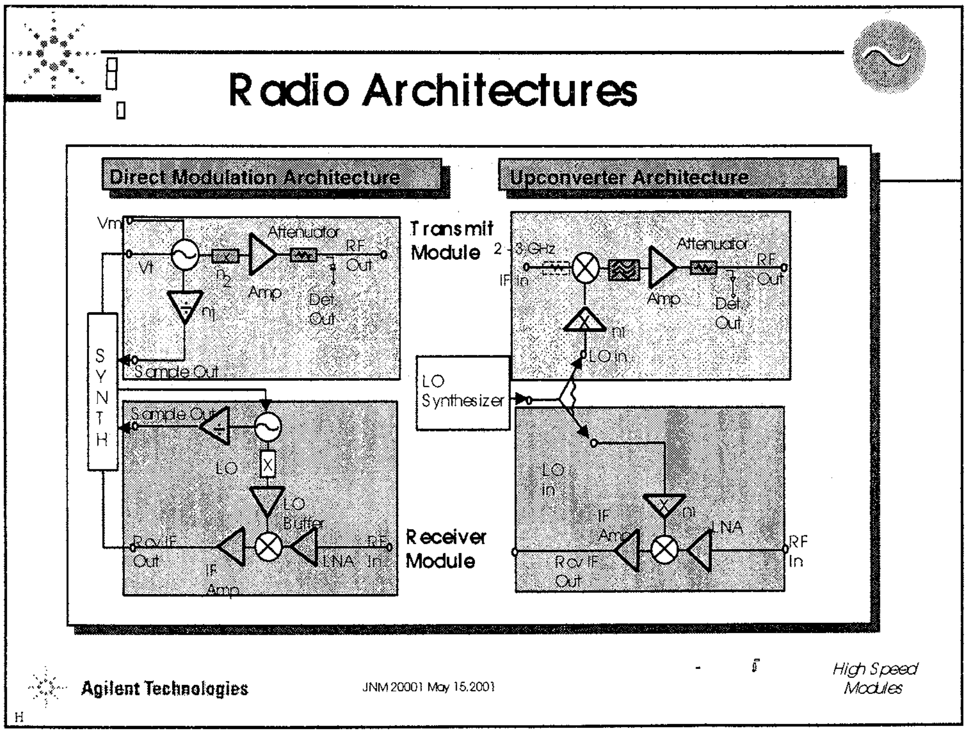

Radio Architectures

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High Speed Modules

Direct Modulation vs. Upconverter Architecture for High Speed Radios

Direct Modulation

- Simpler Architecture using FSK
- Easier phase noise
- Saturated Power Amp.
- Fast Modulable VCO
- Applicable for 59-64 GHz

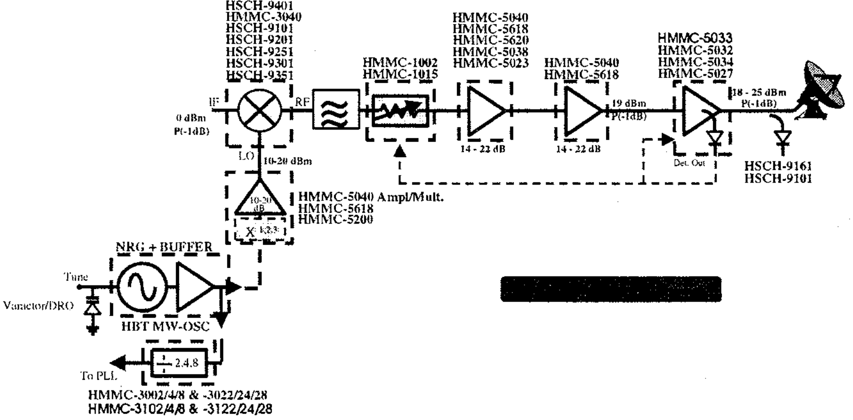
Upconverter

- Higher spectral efficiencies with QAM
- Linear Power
- Lower Phase Noise Reqd (DRO, YTO)
- Applicable for 5.8, 26 - 43 GHz

	Phase Noise	**Amplifier Linearity**
FSK Systems	-60 dBc/Hz @ 100 K	Saturated Output Power
QAM Systems	-90 to -105 dBc/Hz @ 10 KHz	>10 dB back off from P-1

MW/MMW GaAs ICs

Upconverter Transmitter (6-43 GHz) Building Blocks



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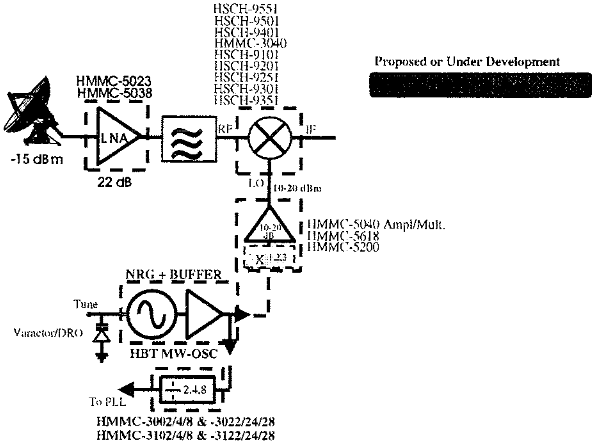
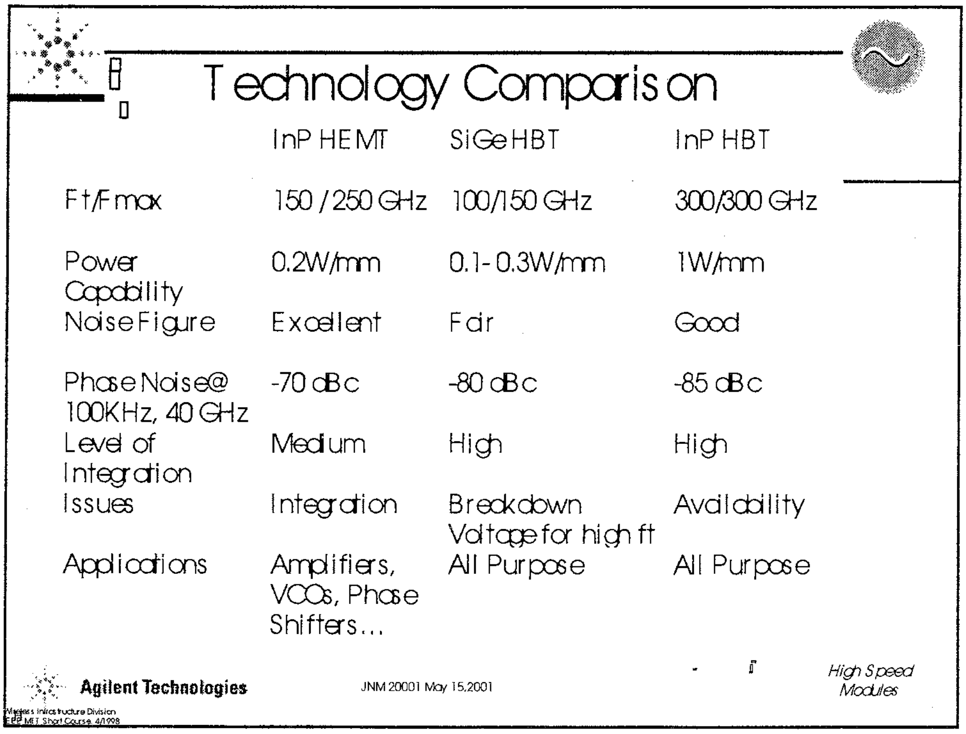
MW/MMW GaAs ICs

Receiver (6-43 GHz) Building Blocks



Oscillator Performance Comparison

Type	**Phase Noise at 38 GHz**	**Comments**
Fundamental MMIC / FET	-70 dBc/Hz @ 100 KHz	Phase Noise OK for FSK
Multiplied BJT microstrip low noise	-95dBc/Hz @ 100 KHz	Fixed Tuned
Multiplied Permanent Magnet YIG Tuned Oscillator	-85 dBc/Hz @ 10 KHz	Tunable Low Noise. Suits QAM applications
Multiplied DRO	-80 dBc/Hz @ 10 KHz	Fixed Tuned



Technology Comparison

	InP HEMT	SiGe HBT	InP HBT
Ft/Fmax	150 / 250 GHz	100/150 GHz	300/300 GHz
Power Capability	0.2W/mm	0.1- 0.3W/mm	1W/mm
Noise Figure	Excellent	Fair	Good
Phase Noise@ 100KHz, 40 GHz	-70 dBc	-80 dBc	-85 dBc
Level of Integration	Medium	High	High
Issues	Integration	Breakdown Voltage for high ft	Availability
Applications	Amplifiers, VCOs, Phase Shifters…	All Purpose	All Purpose

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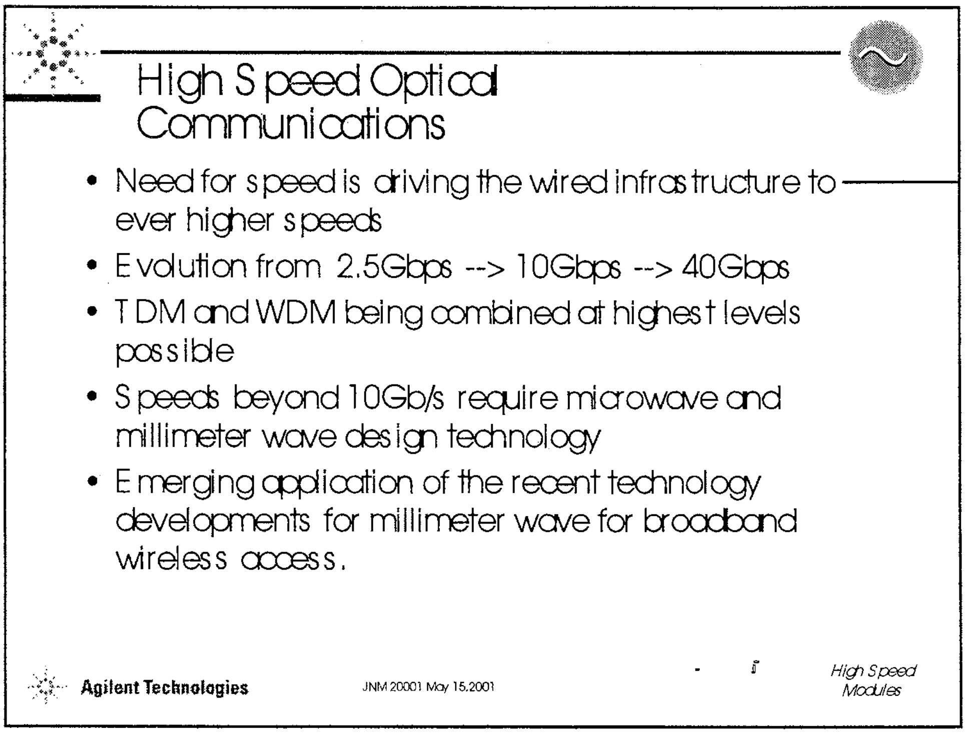
Wireless Infrastructure Division
EEP MIT Short Course 4/1998



High Speed Optical Communications

- Need for speed is driving the wired infrastructure to ever higher speeds
- Evolution from 2.5Gbps --> 10Gbps --> 40Gbps
- TDM and WDM being combined at highest levels possible
- Speeds beyond 10Gb/s require microwave and millimeter wave design technology
- Emerging application of the recent technology developments for millimeter wave for broadband wireless access.

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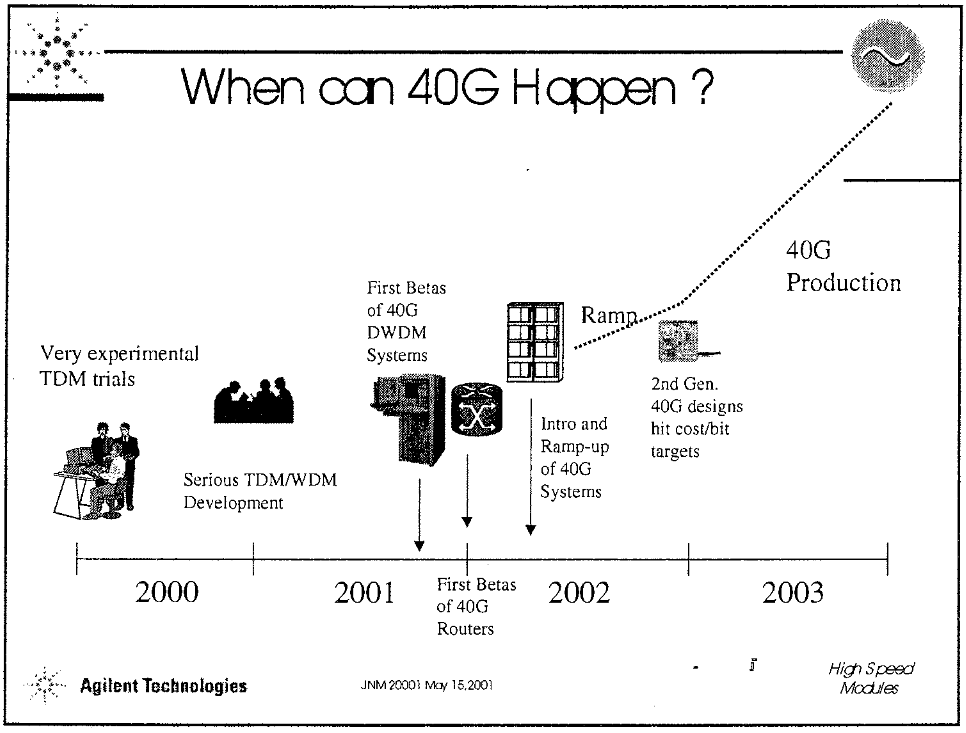
40G Optical Communication Systems

- Why
  - Increased Capacity
  - Reduced Footprint
  - Easier Network Management
  - Higher Spectral Efficieny
  - Reduced cost (per managed bit)
- Where
  - DWDM equipment
    - Long Haul
    - Metro and Short Haul
  - Routers
  - SONET Add/Drop Muxes
  - Optical X-connects

Challenges for 40Gb/s

- Polarization Mode Dispersion
- Chromatic Dispersion
- Old Fiber vs. New Fiber
- Mixed Signal Integration
- Packaging
- New frontier for performance and cost



When can 40G Happen ?

Very experimental TDM trials

Serious TDM/WDM Development

First Betas of 40G DWDM Systems

First Betas of 40G Routers

Intro and Ramp-up of 40G Systems

Ramp

2nd Gen. 40G designs hit cost/bit targets

40G Production

2000

2001

2002

2003

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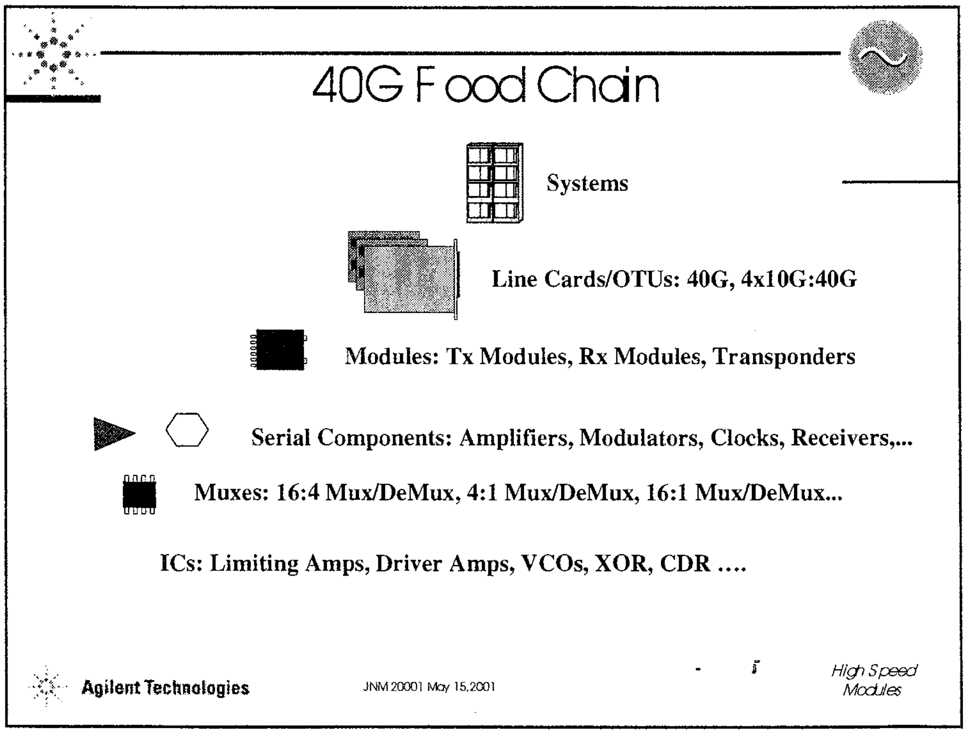

40G Food Chain

Systems

Line Cards/OTUs: 40G, 4x10G:40G

Modules: Tx Modules, Rx Modules, Transponders

Serial Components: Amplifiers, Modulators, Clocks, Receivers,...

Muxes: 16:4 Mux/DeMux, 4:1 Mux/DeMux, 16:1 Mux/DeMux...

ICs: Limiting Amps, Driver Amps, VCOs, XOR, CDR ....

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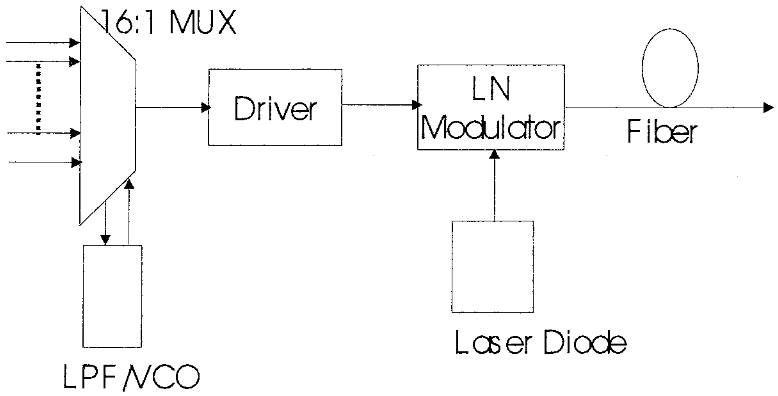
OC-768 Transmitter Block Diagram



16:1 MUX

Driver

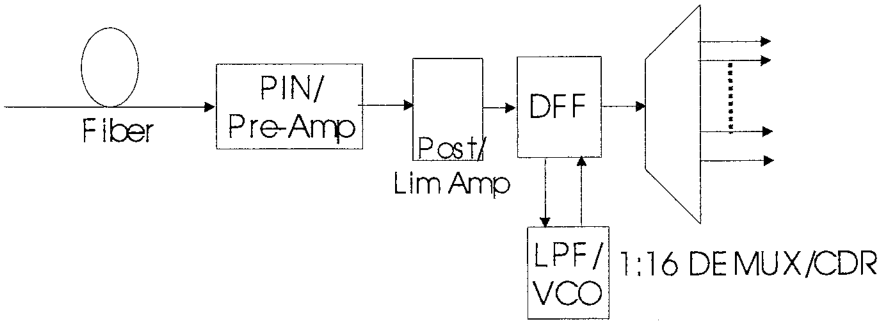
LN Modulator

Fiber

Laser Diode

LPF/VCO

OC-768 Receiver Block Diagram



Fiber

PIN/ Pre-Amp

Post/ Lim Amp

DFF

LPF/ VCO

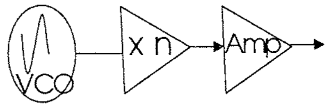
1:16 DEMUX/CDR

VCOs for 40 Gb/s Systems

- Key component for the transceiver
- Determines the Jitter Generation
- Critical requirements
  - Frequencies: 20 GHz / 40GHz
  - Low Integrated Phase Noise over 50KHz and 80 MHz
  - Small Size
- Options
  - Integrated with MUX / DEMUX
  - Discrete VCO

Options for 20GHz and 40GHz Sources

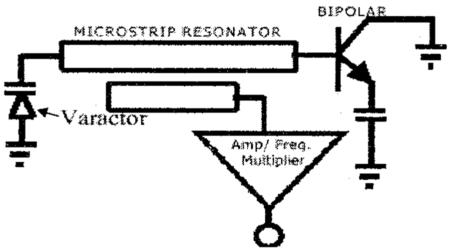
- Fundamental Oscillator
  - Limitations:
    - High Frequency using Silicon Bipolar Device
    - Poor Phase Noise using GaAs FET devices
    - Increased size using a DRO.
- Frequency Multiplied Source
  - Lower Phase Noise
  - Better Manufacturability
  - Subharmonically related spurious
  - Examples:
    - 10 GHz VCO/DRO x 2 OC-768
    - 10 GHz VCO/DRO x 4 OC-768
    - 13.3 GHz VCO/DRO x 3 OC-768



Frequency Multiplied Source

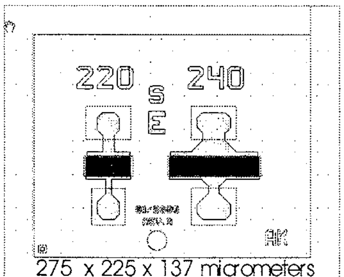
Jitter Contribution:

- Device: Si Bipolar, SiGe, InP HBT
- Resonator Q: Microstrip
- Design: Match, Coupling, Device Line/Load Line



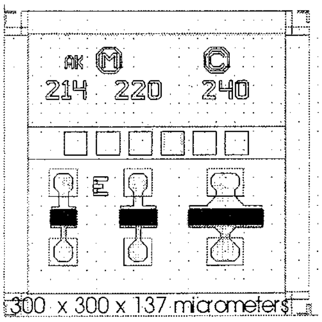
Silicon Bipolar Device

S201



275 x 225 x 137 micrometers

S200



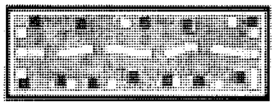
300 x 300 x 137 micrometers

Ft: 10 GHz fmax: 40 GHz.
MAG at 4GHz: 16 dB

0.5 um emitter width 2 um e-e pitch
Corner frequency ~ 10KHz

Frequency Multiplier Devices

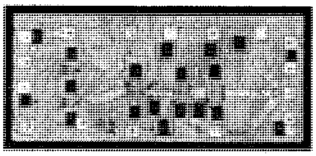
HMMC-5023



Chip Size:	1880 × 600 µm (74 × 23.6 mils)
Chip Size Tolerance:	± 10 µm (± 0.4 mils)
Chip Thickness:	127 ± 15 µm (5.0 ± 0.6 mils)
Pad Dimensions:	80 × 80 µm (3.1 × 3.1 mils), or larger

Used as times two, 21-24 GHz Output, 24 dB gain, 5V 25mA

HMMC-5040

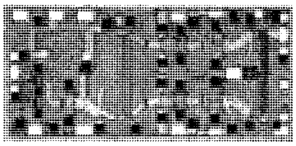


Chip Size:	1720 × 760 µm (67.7 × 29.9 mils)
Chip Size Tolerance:	±10 µm (±0.4 mils)
Chip Thickness:	127 ± 15 µm (5.0 ± 0.6 mils)
Pad Dimensions:	80 × 80 µm (3.1 × 3.1 mils)

Used as times 2 or times 4, 21-44 GHz Output, 22 dB gain, 20 dBm, 4.5V 250 mA

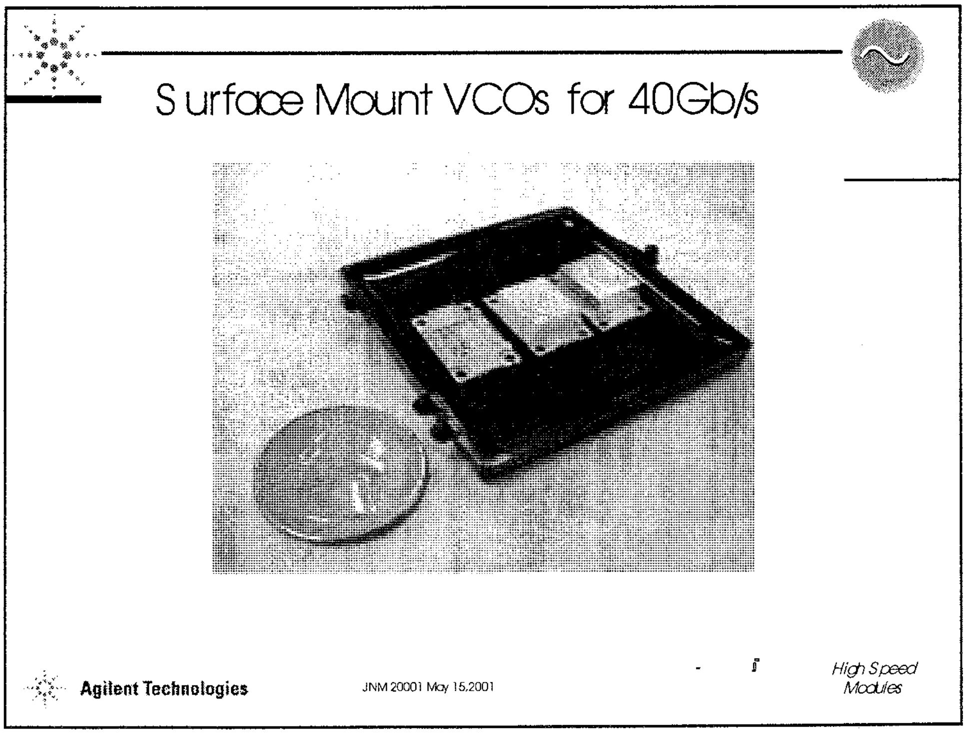
Power Clock Amplifier at 21 GHz

HMMC-5033



Chip Size:	2.74 × 1.31 mm (108 × 51.6 mils)
Chip Size Tolerance:	±10 µm (±0.4 mils)
Chip Thickness:	127 ± 15 µm (5.0 ± 0.6 mils)

Freq. Range: 18 to 33 GHz
>26 dBm Power, 18 dB gain, RF detector and gain/power control



Surface Mount VCOs for 40Gb/s

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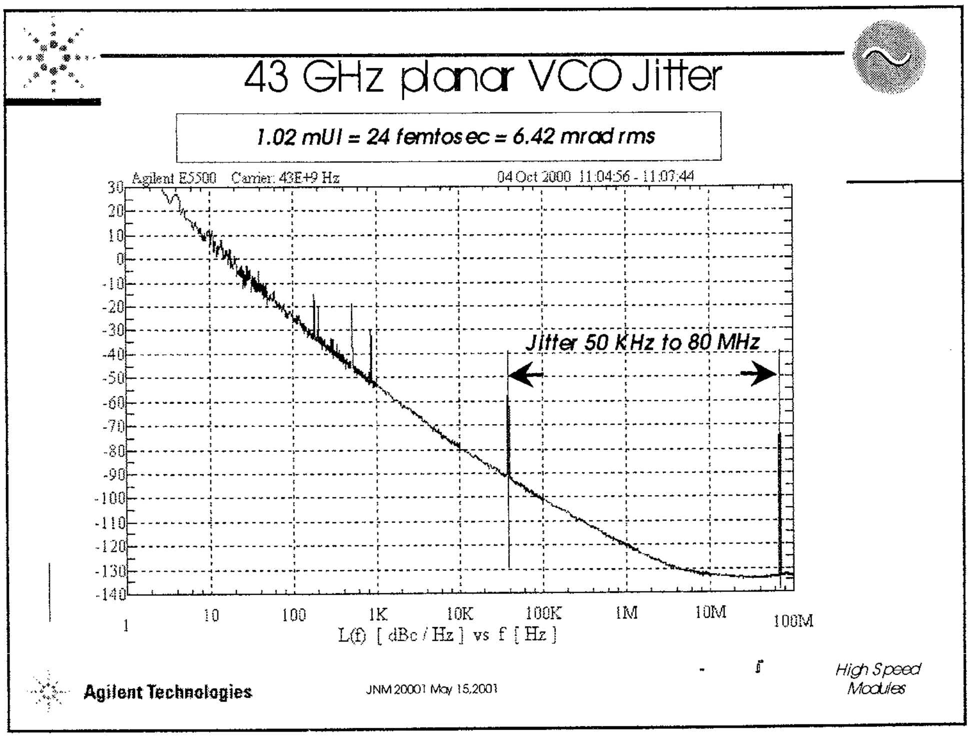
High Speed Modules



43 GHz planar VCO Jitter

1.02 mUI = 24 femtosec = 6.42 mrad rms

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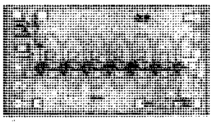
High Speed Modules

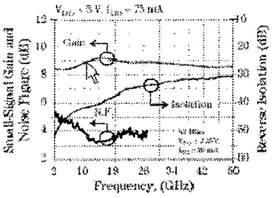
Data Driver Amplifier for 40Gb/s

HMMC-5025
2 - 50 GHz Distributed Amplifier



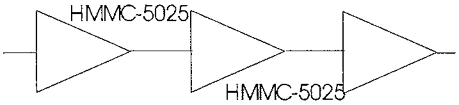
Features

Low frequency performance extension down to 50 MHz	
Gain:	8.5 dB
Gain Control:	30 dB
$P_{(-1dB)}$:	12 dBm
P_{sat}:	16 dBm
$RL_{in/out}$:	15 dB
Chip Size:	1.72 × 0.92 mm



Gain and Isolation vs. Frequency

Driver Amplifier for 40Gb/s Optical Fiber Communication Systems



Specifications

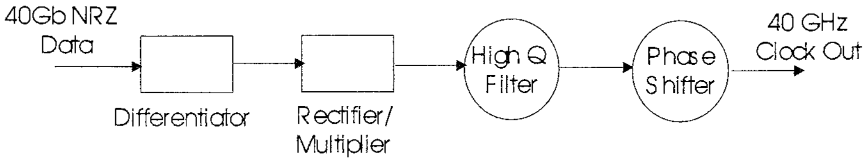
Bandwidth: 50KHz to 45 GHz
Gain: 20 dB min.
Power: 19 dBm (5Vpp)
Gain Flatness: +/- 1.5 dB
Rise/fall time: <10 ps
Group delay: TBD

Module Challenges:

Decoupling Circuit
Bias Tee
Packaging

Clock Recovery at 40Gb/s

- Using PLL
  - Generally implemented as part of DEMUX IC
  - VCO modulation bandwidth and phase noise important.
- Using High Q Filter
  - Simpler architecture
  - Filter stability with temperature critical.



40Gb NRZ Data

Differentiator

Rectifier/ Multiplier

High Q Filter

Phase Shifter

40 GHz Clock Out

Conclusion

- High speeds for wireless and wired applications continue to evolve.
- Status of high speed at 60GHz and OFC Systems (40Gb) reviewed
- Synergy between technologies for wireless and wired applications