Millimetre-Wave Technologies and Applications
- Finally Fulfilling Their Promise

Ian Robertson
School of Electronic and Electrical Engineering
University of Leeds
Why Millimetre-Waves?

High bandwidth for communications

Small high-gain antennas

Special sensing capabilities
A very brief history of early millimetre-wave technology
Linear Millimeter Wave Amplification with GaAs Wafers

H. W. THIM
H. H. LEHNER

Bell Telephone Laboratories
“The waveguide is of high quality; the average measured attenuation varies smoothly from 2.62 dB per mile at 50 GHz to 2.32 dB per mile at 60 GHz”

Precise 50 to 60 GHz measurements on a two-mile loop of helix waveguide
Young, D.T.; Warters, W.D.
The Bell System Technical Journal, 1968
Nobel Lecture: Sand from centuries past: Send future voices fast
http://journals.aps.org/rmp/pdf/10.1103/RevModPhys.82.2299

A Mixer and Solid State L.O. for a 60 GHz Receiver
Dickens, L.E., Jr.; Cotton, J.M.; Geller, B.D.
Microwave Symposium Digest, 1971 IEEE GMTT International

Fig. 1 Scanning electron micrograph of millimetre-wave GaAs IMPATT device

ELECTRONICS LETTERS 19th October 1972 Vol. 8 No. 21
High Data-Rate Solid-State Millimeter-Wave Transmitter Module
Chang, Y.; Kuno, H.J.; English, D.L.
Microwave Theory and Techniques, IEEE Transactions on
Year: 1975,
An experiment on propagation of 60-GHz waves through rain
DeLange, O.E.; Dietrich, A.F.; Hogg, D.C.
The Bell System Technical Journal, 1975
February 1975: Bell completes installation of 14 kilometers of millimeter waveguide in New Jersey

240,000 voice circuits, 17B b/s

“The tubes were full of pure dry nitrogen because oxygen in the air absorbs millimeter waves”

City of Light: The Story of Fiber Optics
By Jeff Hecht

Also, in UK:
White, R.; Read, M.; Moore, A.,

500-Mbit/s QPSK modulation, IMPATT diode oscillators
A 58 GHz Communication Link for Railway Applications
Meinel, H.; Plattner, A.; Pehnack, H.; Schickl, O.
10th European Microwave Conference, 1980

Figure 4:
Two receiver units, mounted on top of diesel rail car
Thick-film fabrication techniques for millimetre-wave dielectric waveguide integrated circuits

Inggs, M.R.; Williams, N.

Electronics Letters, 1980

Fig. 5 Thick-film printed balanced mixer for 60 GHz
A 60 GHz GaAs FET Amplifier
Watkins, E.T.; Schellenberg, J.M.; Hackett, L.H.; Yamasaki, H.; Feng, M.
IEEE MTT-S International Microwave Symposium Digest, 1983
60 GHz high-efficiency InP pulsed TEO
Eddison, I.G.; Davies, I.; Howard, A.M.; Brookbanks, D.M.
Electronics Letters, 1981
Microstrip antennas for millimeter waves
Weiss, M.
IEEE Transactions on Antennas and Propagation, 1981,
A Compact Low Cost 60 GHz Communicator
Hislop, A.
IEEE MTT-S International Microwave Symposium Digest, 1982
Monolithic broadband GaAs f.e.t. amplifiers
Pengelly, R.S.; Turner, J.A.
Electronics Letters
Year: 1976, Volume: 12, Issue: 10
Pages: 251 - 252
1993 >100 GHz amplifier, Wang et al.
1993  2.4GHz single chip transceiver, Devlin et al.  3.3x5.2 mm
1993  2.4 GHz wireless LAN system, Williams
A selection of notable early UK efforts in millimetre-wave wireless communications
M3VDS, BT Martlesham
Millimetre-wave multichannel multipoint video distribution system
Dave Wake (BT / Microwave Photonics) and colleagues
Passive picocells and radio-over-fibre

**Video transmission over a 40 GHz radio-fibre link**
Wake, D.; Smith, I.C.; Walker, N.G.; Henning, I.D.
Electronics Letters, 1992


Fig. 1 Layout of 40 GHz radio-fibre video transmission experiment
Radiant Networks
MESH network
MOBILE BROADBAND SYSTEM
A Report on the work of RACE Project 2067
J.T. Zubrzycki, BBC R&D
A 3D raytracing model for the study of sectored antenna performance in indoor radio communications systems
Algiannakis, C.; Robertson, I.; Aghivami, A.H.
Personal, Indoor and Mobile Radio Communications, 1995. PIMRC'95

Integrated endfire sectored antennas for microwave and millimeter wave LANs
Passiopoulos, G.; Robertson, I.D.; Grindrod, E.
International Conference on Antennas and Propagation, 1997

King’s College / DRA Malvern Project
1995 onwards & where are we now?

- Explosive growth of wireless systems
- Si RFIC technology
- Rock bottom prices
- Transfer of manufacturing
- Consolidation of companies
Q: What stopped wireless millimetre-wave communications being adopted earlier?

Cost of hardware

Video compression techniques

MIMO
CMOS Technology Development and $f_t$
Now focus on "affordable" III-V technologies

Steerable Antennas

Typical current phone

45 GHz, 0.5 W world record in 2013

300 GHz, 10 mW in 2014
Samsung claims 5G tech breakthrough  May 2013

Samsung Electronics says it has developed a technology that could be "at the core" of the eventual 5G mobile-data standard.

The company says its equipment is capable of transmitting data at more than 1Gbps across a distance of up to 2km (1.2 miles).

Samsung says it has developed the world's first "adaptive array transceiver" technology, an innovation that allows part of the super-high-frequency Ka band of the radio spectrum - at 28GHz - to be used for cellular data transmission.

64 antenna elements
Can millimetre-wave communications make it into consumer products?
CablestoGo
60 GHz Wireless HDMI
From Dabs.com
A 4-GBPS UNCOMPRESSED WIRELESS HD A/V TRANSCEIVER CHIPSET
Jeffrey M. Gilbert, Chinh H. Doan, Sohrab Emami, C. Bernard Shung
0.38 THz FMCW radar transceiver
PhD Thesis: *Fully Integrated Silicon Terahertz Transceivers for Sensing and Communication Applications*, Jung-Dong Park, UC Berkeley
Silicon can’t do everything: Transceiver system partitioning
Heterogeneous Integration of Silicon & III-Vs

- Silicon IC for DSP, analogue baseband, IF and low power RF circuits
- III-V devices
- BGA package for integration onto standard FR-4 board
Do we really need millimetre-waves? **YES!**

**High data rate communications**
**Miniature Radars & Sensors**

**New forms of human-computer interaction**

**Augmented Reality**
Microsoft Hololens Project XRay

The ARQuake Project
http://wearables.unisa.edu.au
Q: Will 5G use millimetre-waves?

Obviously YES!

- Already using them for wireless backhaul
- 60 GHz WiFi should be seamlessly integrated into 5G
More sustainable energy systems

Better healthcare

Safer, less polluting, transport

Better security

Assisted living

Stunning Entertainment
Q: Will we really see millimetre-wave transceivers with steerable antennas on lamp posts?

Discuss............