RECENT ADVANCES ON MILLIMETERWAVE PCN SYSTEM DEVELOPMENT IN EUROPE

- an invited survey -

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ABSTRACT

The possibility to apply millimeterwaves for various applications in the commercial arena has a long history, as the technical advantages being offered by such systems are known since more than 3 decades. Within the last 5 years the necessity of turning their attention away from the military sector towards commercial products has forced more and more companies to look at millimeterwave communications very thoroughly. As a matter of fact and fortunately this was accompanied by the advent of low-cost integration procedures, i.e. Hybrid- and Monolithic-Integration Techniques, respectively. Having the necessary technology at hand, mature and commercially available, a wide field of employment areas has been opened. From *indoor high-speed radio communication systems* at 10.6 GHz, as proposed by NTT of Japan, over *"gateways"* for mobile or new, 'deregulated' stationary telephone systems at 38 and 55 GHz, being available from *northern telecom*, UK, and *WLAN's* at 60 GHz, like the MBS project, being under research within the European RACE-programme, to the *optic microwave hybrid approach* for pico-cellular PCN's, as proposed by ALCATEL-SEL of Germany and CNET of France the scope of today's applications is spanning. While the military market is still decreasing, the commercial application of millimeterwaves is ongoing to increase very rapidly. The actual status and the upcoming technology trends, as they can be seen from Europe, will be surveyed.

1.0 INTRODUCTION

The necessity of turning their attention away from the military sector towards commercial products has forced more and more companies to look into millimeterwave communications. The *Information Technology Age* is rising and as a matter of fact this is accompanied by the advent of low-cost millimeterwave integration procedures, i.e. Hybrid- and Monolithic-Integration Techniques, respectively. A wide field of employment areas has been opened: from *indoor high-speed radio communication systems*, over *'gateways'* for mobile telephone systems to *WLAN's*, either based on millimeterwaves directly or on the *optic microwave hybrid* approach, incorporating fiber-optical distribution before transmitting in the millimeterwave range, the scope of today's applications is spanning. Two major and generally different application areas have to be distinguished: 'gateways' for mobile and new, 'deregulated' stationary telephone systems, i.e. point-to-point transmission links, and WLAN's, i.e. point-to-multipoint networks. Apart from very different system design and requirements, the same component technology, even identical devices, can be and have been taken to realize such systems.

2.0 *'gateway'* - TRANSMISSION LINKS

Today the area of mobile telephone systems is expanding rapidly. GSM (Groupe Special Mobile), the Pan-European digital mobile cellular network [1] has already become the worldwide driver. Mobile telephones under GSM communicate at 0.9 or 1.8 GHz within cell sizes of 1 to 5 km in diameter; groups of five to 20 of these cells have to be linked to a base station and this is more than a *valuable niche market*, where millimeter radio fits in. MRC - California Microwave's Microwave Radio Corp. has reported more than US $ 9 million of 38 GHz equipment sales since the 4th quarter of 1992 [2]. Depending on the hop length being necessary topologywise, 23, 38, 42 or 55 GHz usage is appropriate. Table 1 displays the according *Channel Plan and Equipment Regulatory Specifications*, being proposed by the Radiocommunication Agency of London, UK, in 1990, being the UK-standard now. [3]. Untill today, hybrid millimeterwave technology was employed mostly. However, MMIC technology is incorporated now, as it has become available.

	FREQUENCY BAND		
TRAFFIC CAPACITY	38GHz	55GHZ	58GHz
	CHANNEL SPACING (MHz)		
2Mbit/sec	14	25	100
8Mbit/sec	28	50	100
34Mbit/sec	56	75	100
140/155Mbit/sec	140	150	*
NARROWBAND TV	28	*	100
COLOUR TV/RADAR REMOTING	56	*	100
GO/RETURN SPACING (MHz)	1260	> 500	N/A
FREQUENCY STABILITY (+/- MHz)	4	9	36

Table 1:
Channel plan and equipment regulatory specifications
(from [3])

A number of new 38 GHz equipment manufacturers have appeared on the market lately, DMC - Digital Microwave Corporation and P-COM in the US or TSI in the UK, to mention just three. Accordingly, Alpha Industries Inc. of Methuen, PA, USA, has delivered more than 2,000 of monolithically integrated 38 GHz-chip-sets in 1994 alone [4], as Alpha Industries Inc., together with Philips TRT, is one of the two major 38 GHz component and chip-set providers, respectively.

2.1 40 DR - 38 GHz northern telecom SYSTEM.

An example of such a cooperation is the *40 DR* communication system built by northern telecom Europe, Ltd. of Paignton, England, for British Telecom [5]. The employed monolithically integrated 38 GHz GaAs MMIC chip-sets are commercially available from Alpha Industries of Methuen, MA, USA [6]. The transmitter module, fig. 1, is based on two MMICs, a voltage controlled oscillator and a power amplifier, the other components within the (26 x 26 x 13) mm module, being hybrid integrated and used for PLL type frequency stabilization, temperature compensation, and bias regulation. The output power is specified to be larger than 50 mW. The receiver module actually is slightly larger in size, and it draws on a combination of GaAs MESFET, Schottky and Si MMIC technologies. The mixer is a GaAs MMIC; a Schottky-diode based rat-race-balanced device, with an IF frequency-range between 10 MHz and 1 GHz. Taking a Si MMIC for the IF amplifier, the resulting DSB phase noise is quoted to be 5.5 dB.

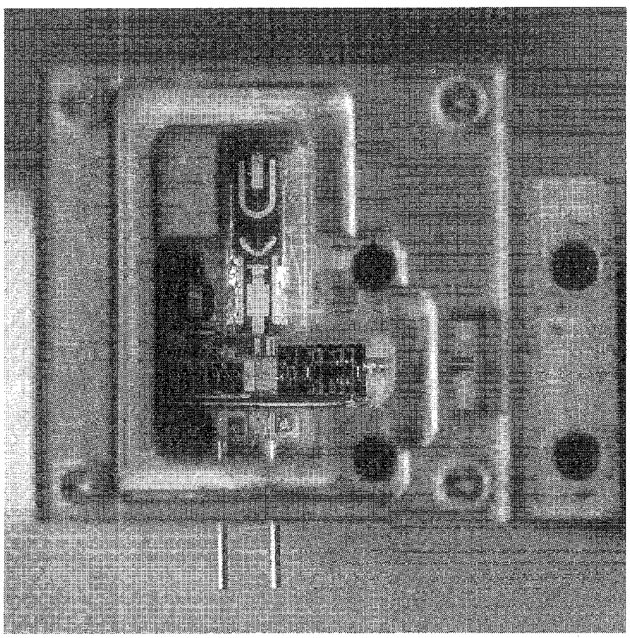

Figure 1:
Ka-band MMIC transmitter
courtesy of Alpha Industries Inc.

The entire RF unit is housed in a weatherproof enclosure, that can be mounted directly to the antenna. Precision high-performance antennas, being of the center fed reflector type, are available indifferent diameters. The 300 mm diameter antenna, for example, has 37 dBi of gain and maximum sidelobe levels 23 db down at +/- 5 degrees from boresite at 38 GHz. Being built according to CCITT Rec. G. 703, 742, and 823 regulations [5] the available voice channel capability spans from 30 to 120, depending on the installed digital interface - CEPT 1 or CEPT 2.

2.2 DEVELOPMENT TRENDS

Based on these promising results, further research and development is ongoing. While the University of Bologna, D.E.I.S., Italy, has solved the the yearlong discussion on how to model a 60 GHz transmission channel, RICE or RAYLEIGH - it is RICE for shorter distances only [7]- the University of Bradford, UK, has taken an overall approach. In order to compensate for 60 GHz channel and component disadvantages the system design and modulation scheme is adjusted accordingly [8].

3.0 WLAN's - Wireless Radio LAN's (Local Area Networks)

In recent years, there has been a continuing trend towards ever smaller and more portable telecommunications equipment, providing an opportunity to meet the demand for local networking via wireless access; as wirelessness provides a number of significant potential benefits[9]:

- ease and speed of ***installing or altering*** LAN systems - ***portability / mobility*** - ***cost,*** while there are no savings in the initial installation cost of WLANs, the real cost benefits are long term - and last not least, WLANs can be used where ***cables cannot be installed***, e.g. in historical buildings -

3.1 INDOOR K-Band NTT SYSTEM

A very good example demonstrating the last statement - even if it is not millimeterwaves nor European - is the *indoor high speed communication system*, built by NTT of Kanagawa, Japan [10], at K-Band (18-19 GHz).

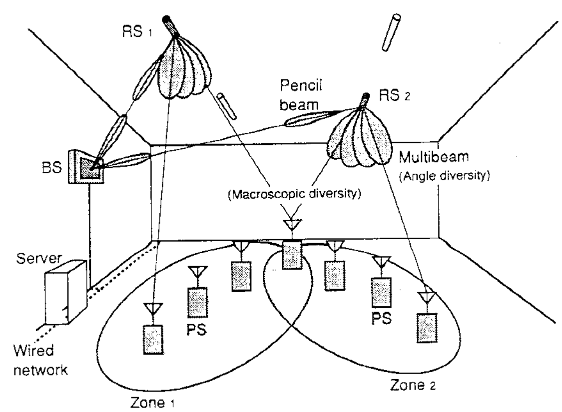

Figure 2:
Indoor K-Band high-speed radio communication system
(from: Uehara et al. [10])

The proposed concept places the base station (BS) to the wall, where it can be wired and connected to the stationary network quite easily, while the ceiling mounted stations (RS) link the BS to the personal stations (PS), figure 2. The installation requirement for the RS is very pragmatic, it simply replaces an already installed flourescent tube. Delay spread calculations and first RS prototype antenna measurements have been carried out - narrower beamwidth provides less delay spread, being necessary to ensure low bit-error-rates.

As the radio frequency spectrum is a ***limited natural resource***, there is considerable competition for its use and the easily accessable bands have become more and more congested. New frequencies can only be made available by moving into the higher frequency regime. Around 60 GHz, radio waves are significantly attenuated by absorption due to the oxygen content of the atmosphere. This will be of benefit in system design, since interfering signals have a very short range and hence frequencies can be re-used more efficiently. Work in this area has as well been carried out in Japan. AMWT of Tokyo has thoroughly investigated the propagation behaviour, and especially the delay spread problem for 60 GHz indoor communication LAN's [11].

3.2 RACE project 2067 MBS - Mobile Broadband System.
The *RACE project 2067* ***MBS - Mobile Broadband System,*** being jointly under development by 18 European partners [12, 13], addresses the 60 GHz system concept, the techniques and the technologies required for the set-up of the Mobile Broadband System, as well as market and economical issues, related to the widespread introduction of corresponding systems and services. The demonstrator consists of a mobile transmitter and a base station receiver, which together are able to perform high data rate (32 Mbit/s) video transmission. The main programme objective is to specify, design, simulate, fabricate and test the building blocks of this transceiver working in the 62 to 66 GHz band, and using GaAs MMIC technology. Three building blocks, (1) phase locked, low noise local oscillator - realized chip shown in figure 3, (2) high dynamic range upconverter, and (3) low noise down converter, are under development at the time. First results for the upconverter (2) exhibit a conversion gain of 0 dB (+/- 1 dB) for an input power of 10 dBm over a an IF range of 5.2 to 6.2 GHz with good agreement between simulated and measured results [14].

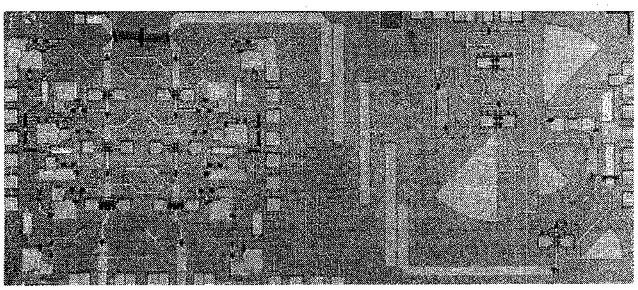

Figure 3:
RACE project 2067 MBS
local oscillator chip
(from: [12])

3.3 OPTIC MICROWAVE HYBRID LANs
The employment of fiber-optical distribution for LANs was - to the author's knowledge - first proposed by ALCATEL-SEL of Pforzheim, Germany [15], and CNET of Lannion, France [16]. Following the so dubbed *optic microwave hybrid* approach a mobile broadband communication system can be realized economically attractive. A large number of very simple base stations (bs), figure 4, requiring only low power and being easily upgradeable to higher capacity are connected to the main base unit by means of optical fibers, wireless transmission takes place in the microwave (2.45 GHz CNET) or millimeterwave (40/60 GHz, ALCATEL-SEL) region. The general problems of this approach and their different solutions are discussed thoroughly in [17].

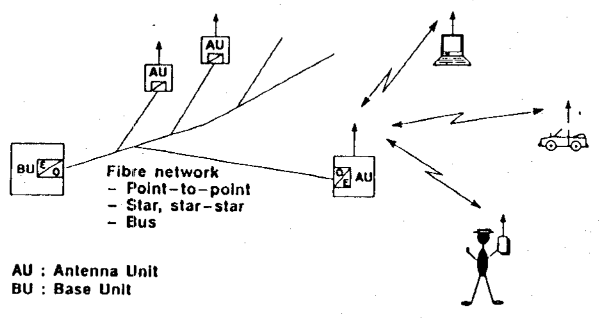

Figure 4:
Basic architecture of *optic microwave hybrid* distribution system
(from: Heidemann et al. [15])

3.1.1 *RACE project 2005* - ***MODAL*** . Within the *RACE project 2005* ***MODAL - MICROWAVE OPTICAL DUPLEX ANTENNA LINK*** [15], the generation of the millimeterwave carrier is performed indirectly. Two optical carriers with a frequency difference equal to the desired millimeterwave frequency - 40 GHz - are generated; one of which being modulated - in amplitude, frequency, or phase. Being transported to the micro-bs via the fibre-network, the optical carriers are heterodyned, using a PIN - diode. The downconverted millimeterwave signal is amplified and radiated. Employing Erbium-doped fibre-optic amplifiers, transmission over 8, 20, and 40 km was tested; no degradation of the millimeterwave signal was observed.

Generally following the same *optic microwave hybrid* approach, but incorporating *'passive terminal stations'* at 2.45 GHz for the micro-bs', tests were carried out by CNET [16], giving more than promising results: a BER of 10^{-7} was achieved for a bit rate of 192 kbits/s.

4.0 CONCLUSION

These examples testify the viability of the millimeterwave approach, point-to-point and point-to-multipoint communication links at 38, 42 and 55 GHz will complement today's already existing microwave transmission systems, such links will especially be taken as easy to install "gateways" *within more complex communication networks like GSM or new stationary telephone systems. The frequency range of 58 or 62 to 66 GHz will be taken for short range WLAN's, various indoor and outdoor applications are upcomming. A commercially successful and effective innovation process in the microwave industry has been started, however, there is still need for more creative and active collaboration between the experts, particularly between the service providers and the electronic engineers; the gap between manufacturer and customer, and even more the end user, has to be closed.*

*Millimeterwave applications and technologies, being initiated, fostered and pushed by military needs first, have arrived in the commercial arena and will be the "*backbone*" for the future.*

5 0 ACKNOWLEDGEMENT

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6.0 REFERENCES

[1] Picken, P.: New aspects of RF and signalling measurements in the GSM networks, German IEEE MTT/AP Chapter, Workshop on *Mobile Microwave Radio Services*, Sept. 24/25 1992, TU Ilmenau, Germany, 64-72.

[2] GaAs Lights 93-2, Strategies Unlimited, Mountain View, CA, 13.

[3] Business Opportunities in the Millimetric Bands, Seminar of the EEA & RA, London 27th June 1990.

[4] Stewart, E., Alpha Industries Inc., Methuen, PA, private communication.

[5] nt - Northern Telecom Europe Ltd., data sheet 1992: 40 DR, 38 GHz Digital Millimetric Radio.

[6] Rafaelli, L., Stewart, E.: A standard monolithic transmitter for 38 GHz PCN applications, Alpha Industries Inc., Methuen, PA, literture service..

[7] Andrisano, O., Daniele, P., Frullone, M., Verdone, R.: Roadside to vehicle communications at 60 GHz, 24th EuMC 1994, Cannes, France, Workshop 4 on *Short Range Radio Communications,* Workshop Proc. 180-185.

[8] Hunter, I.C., Watson, P.A., Young, D., Field, P.L.: Develoments in component technology for 60 GHz radio links, MM '92, Brighton, England, Conf. Proc. 99-103.
Field, P.L., Jones, A.E., Hunter, I.C., Gardiner, J.G.: Phase noise requirements for mm-wave transceivers, IEE Colloqium on *Measurement and Modelling of Phase Noise in Microwave and Millimeter Wave Circuits*, 1993 England.

[9] Halls, G.,: Wireless LANs - how they work, Roke Manor Research Ltd., 1-10.

10] Uehara, K., Seki, T., Kagoshima, K.: New indoor high-speed radio comunication system, 1994 Asia-Pacific Microwave Conference - APMC'94, Tokyo Dec. 1994.

[11] Takimoto, Y.; Inoue, A.: Study on minimum delay spread conditions for millimeter-wave indoor LAN's, Microwaves '94, London, UK, 25-27 Oct. 1994, Symp. Dig. 386-391.

[12] Fernandes, F.: Progress towards a mobile broadband system, Microwave Engineering Europe, Nov. 1993,17-25.

[13] Plattner, A.: Technology and demonstrator ot the RACE project 'Mobile Broadband System', 1994 IEEE MTT-S Digest, paper WE1D-4, 639-642.

[14] Focus on MMIC's, , Microwave Engineering Europe, Feb. 1994,17-18.

[15] Heidemann, R., Hofstetter, R.: A novel optical mm-wave generation and tranport system, MIOP '93, Sindelfingen, Germany, May 1993, Symp. Dig. 251-254.
Heidemann, R., Hofstetter, R., Schmuck, H.: Fibre-optic technologies for 30/60 GHz pico-cellular PCN and mobile systems, 1994 IEEE MTT-S Digest, paper WE1D-3.

[16] Meyer, S., Guena, J., Leost, J.C., Penard, E., Goloubkoff, M.: A new concept of LANs: Passive microwave links hooked onto a fiber optic backbone, IEEE MTT-S 93, Atlanta, GA, USA, June 1993, Symp. Dig. 1549-1552.

[17] Nowak, W.: Fibre-optic transmission to Basestations for future mobile radio networks, private communication.