Millimeter wave applications and technology trends

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Abstract

Over the past two decades millimeter wave technology was fostered by military needs and applications, as it offers a number of commonly known advantages, such as narrow beamwidth with relatively small antenna dimensions, high radar resolution and high radar cross section, as well as small size and lightweight equipment. However, wide spread application was hampered due to the lack of suitable power sources and the comparatively high component costs. As corresponding research and development efforts were ongoing worldwide since the early 1970's, today's component technology, e.g. planar and quasi-planar technology for hybrid integration, is not only available, but mature and widespread. Two major market oriented employment areas can be distinguished nowadays, communications and traffic-control systems, the earlier being either point-to-point or LAN systems, the later incorporating radar- and beacon-systems. Millimeter wave systems have found an increasing interest for such purposes, due to their specific advantages, as well as the lack of frequencies for new services. While the military market is decreasing, commercial applications of millimeter waves are increasing rapidly.

Key words : Millimetric wave, State of the art, Radiocommunication, Radar, Military application, Road traffic.

TENDANCES DE LA TECHNOLOGIE ET DES APPLICATIONS DES ONDES MILLIMÉTRIQUES

Résumé

Durant les deux dernières décades, la technologie des ondes millimétriques était stimulée par les besoins et les applications militaires. Elle offre de nombreux avantages tels qu'un faisceau étroit avec des dimensions d'antenne réduites, une résolution radar et une section efficace radar élevées ainsi qu'un équipement léger et de petite dimension. Cependant les applications à spectre larges sont handicapées par le manque de sources de puissance adéquates et le coût élevé des composants. Au fur et à mesure des progrès en recherche et développement sont réalisés à l'échelle mondiale depuis les années 70, la technologie des composants actuelle comme par exemple celle des dispositifs planaires et quasi-planaires pour l'intégration hybride et non seulement disponible mais mûre et très commune. Deux domaines d'utilisation orientés vers le marché peuvent être mis en évidence : les télécommunications et les systèmes de contrôle de circulation routière. Le premier couvrant les systèmes point-à-point ou les réseaux locaux d'entreprise, le second englobant les systèmes radar ou à balises. Les systèmes à ondes millimétriques ont trouvé un intérêt croissant pour ces applications grâce à leurs avantages spécifiques et au manque de fréquences disponibles pour les nouveaux services. Tandis que les applications militaires diminuent, les applications commerciales des ondes millimétriques augmentent rapidement.

Mots clés : Onde millimétrique, Etat actuel technique, Radiocommunication, Radar, Application militaire, Circulation routière.

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I. INTRODUCTION

Three general fields of employment have to be distinguished today, communication and radar, being phenomenological applications as well as automotive traffic control, a market driven application, combining the earlier two [2, 3, 31]. Apart from the unique propagation behaviour [1], millimeter wave applications take advantage of the highly directive nature of the millimeter wave beam, i.e. good angular resolution can be achieved with moderately small antennas, thus millimeter wave systems are small in size and light in weight, compared to their microwave counterparts. The lack of frequencies for new services in the microwave bands commonly used today, is an additional important reason.

II. COMMUNICATIONS

Atmospheric propagation effects strongly influence considerations related to the application of millimeter wave transmission. Normally such systems will be operated in the atmospheric windows around 35 and 94 GHz [1]; for specific applications, like LPI (low probability of intercept) radio links, the maximum absorption range around 60 GHz will be taken.

II.1. 60 GHz Marconi binocular radio.

A state-of-the-art 60 GHz product developed for this purpose is displayed in Figure 1. This prototype voice communication link, realized by Marconi of Stanmore, England [6], consists of 3 units, the battery box and power supply, the headset with microphone and the binoculars, containing the transmitting and receiving circuitry as well as the optical sight:

- output power: 50 mW,
- conversion loss: 7 dB,
- antenna gain: 25 dB.

Employing hybrid integration technique, i.e. MIC on quartz, made it possible to integrate the entire RF unit, 6 discrete components, within one half of a standard binocular. Thus a quite complex system realization, incorporating modulator, iso-circulator, separate LO-path, etc., could be accomplished.

This first example already shows, what can be done in the millimeter wave range, using today's available technology.

The employment of the 40-50 GHz band for EHF military satellite up-links has been very important for the development of millimeter wave technology. This frequency band offers increased bandwidth over the UHF and SHF bands being in current use today and permits the construction of small terminals; thus covert operation for various military platforms is achieved. The Skynet 4 series of satellites in the UK [7] and the Milstar program in the US are such applications.

Today the field of mobile communication is moving rapidly, crossborder agreements in Europe have paved the way for a GSM (Groupe special mobile) Pan-European digital mobile cellular network, because the demand for communication services that can be provided without the need for cable connections is growing. Potential users become aware of the advantages gained from services such as cordless telephones and mobile cellular radio.

« The potential to use millimeter radio in such networks is great and may well become the major economic driver implementing such a network » [8].

Mobile telephones communicate at 1.8 GHz within cell sizes of 1 to 5 km in diameter; groups of five to 20 to these cells have to be linked to a base station and this is the valuable niche market, where millimeter radio fits in. Depending on the hop length, 38 or 55 GHz usage is appropriate, thus the commercial exploitation of this greatly underutilised region of the frequency spectrum is upcoming.

Besides this future niche market the main employment area for millimeter wave communication equipment today is in connecting subscribers, for example in private data TV and telephone circuits. More than 1,000 systems have become operational since the late 1970’s, mostly in Japan, but also in Europe [9]. Hybrid millimeter wave technology was employed successfully. However, MMIC technology will be incorporated now: after several years of successful operation the entire frontend of the 26 GHz BTRL prototype communication system, Figure 2, is in the process of redesign, incorporating monolithic circuits [13].

II.2. 50 GHz Matsushita system.

A good example for a transmission link making use of state-of-the-art semiconductor technology is the 50 GHz Matsushita system, built by Matsushita Electric Ltd. of Osaka, Japan [14]:

- output power: 10 mW,
- receiver noise figure: 13 dB,
- Frequency stability: \(\pm 100 \cdot 10^{-6} (-20 \ldots +60^\circ\text{C})\),