CANADIAN GaAs IC DEVELOPMENTS FOR COMMUNICATION APPLICATIONS

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ABSTRACT

Canada's large landmass and the remote locations of many of its communities have placed great importance on long distance and high speed communications. Satellite communications continues to provide links to remote communities but the growing demand for bandwidth is leading the drive towards higher frequency bands and there is also an increasing emphasis on communication to personal mobile terminals. Today, new terrestrial wireless systems are also appearing to meet the human desire for high speed digital communications from the home, car, office or even golf course. This article presents an overview of some of the more significant GaAs IC developments achieved in Canada for commercial communications in the last few years.

INTRODUCTION

Human communications are undergoing a dramatic revolution driven by an ever growing desire to transfer an ever increasing amount of information in a variety of forms - voice, text, data, video, etc. The "multimedia" nature of this information requires higher and higher speed communications systems and the faster data speeds demand larger bandwidths. This new information world is based on digital data and is being implemented in high speed wireless technologies at high microwave frequencies because they offer not only a practical solution but also facilitate rapid deployment of new systems.

TERRESTRIAL WIRELESS COMMUNICATIONS

The proposed Local Multipoint Communication System (LMCS in Canada, LMDS in the U.S.) was announced in late 1996 [1] and licenses were issued to three Canadian companies to provide wireless services. The system is intended to deliver two-way, wireless communications to businesses and private residences for high speed multimedia communications such as Internet, television, movies, video games, etc. Signal distribution will be in a cellular format, each cell ranging from 5 to 10 km in diameter, and in the initial deployment the frequency band will be 27.35 - 28.35 GHz. At a future date a second band is planned at 25.35 - 27.35 GHz.

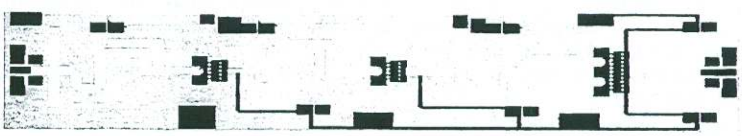


Figure 1. 20 dB gain PHEMT driver for LMCS applications.

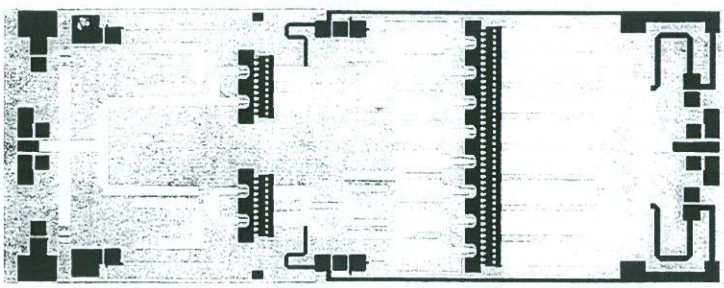


Figure 2. 1 Watt, 10 dB gain PHEMT power amplifier chip covering 27-30 GHz.

Several companies are currently developing LMCS subsystems and one of the key MMIC components is a 1 Watt power amplifier for the transmit chain. Figure 1 shows the driver amplifier and Figure 2 illustrates the associated power amplifier developed at CRC using an external foundry. The two chips were fabricated with a 0.18 μm PHEMT technology. The three stage driver consists of two 500 μm devices followed by a 1.0 mm device. Right angled, coupled microstrip lines are used for interstage coupling and allow for DC bias isolation while avoiding the inherent tolerance spread associated with conventional overlay capacitors. The right angles also aid in overall circuit size reduction. The driver chip measures 5.3 x 1.4 mm and provides 25 dB gain over the frequency range 27 – 30 GHz. The power amplifier measures 5.3 x 2.1 mm and uses two 1.0 mm PHEMTs in parallel to drive a single 4.0 mm PHEMT. Coupled microstrip lines are again used between stages.

CRC is exploring the application of future higher frequency bands for terrestrial communications and recently developed a 60 GHz subharmonic mixer for a receiver front end [2]. The 59 - 61 GHz MMIC was designed around a pair of PHEMT based anti-parallel diodes (Figure 3) and was tested with a 10 dBm, 29.5 GHz local oscillator (LO) source. It is free of spurious products except for a local oscillator feedthrough level of –42 dBm. The conversion loss is approximately 12 dB.

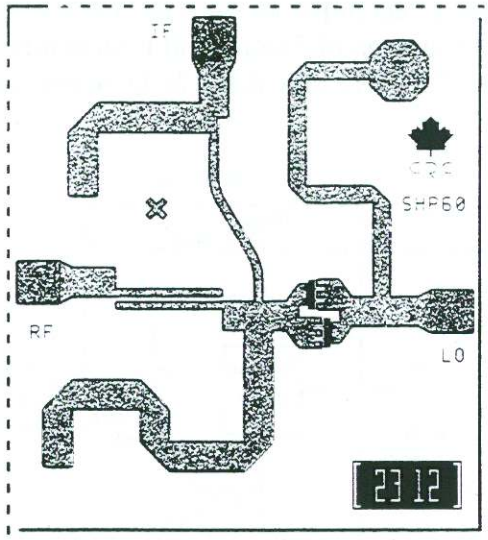


Figure 3. 60 GHz Subharmonic mixer MMIC, 1.2 x 1.3 mm.

SATELLITE COMMUNICATIONS

While high speed data communications are becoming available between fixed locations, there is also a desire to have similar communications when a person is away from his/her home or office. In a country such as Canada, where there are many isolated communities far from wired or even wireless communication systems, satellites can be used for remote communications. CRC has

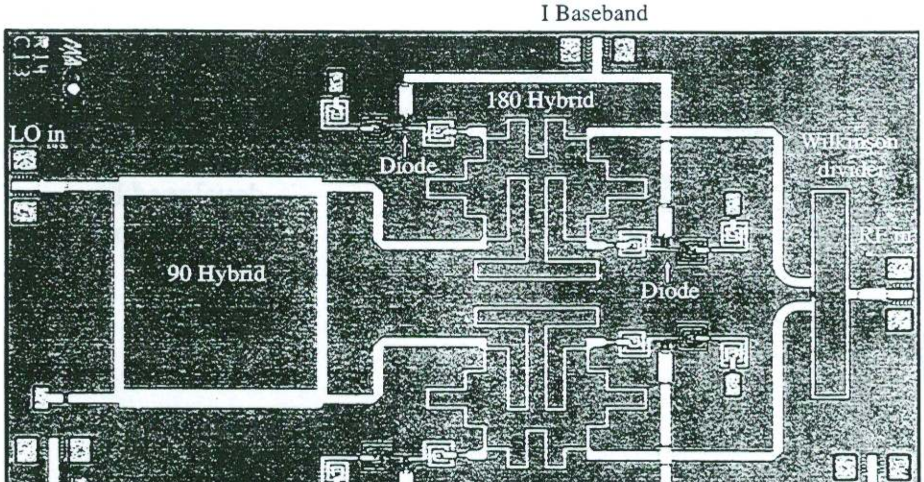


Figure 3. K-Band direct I & Q demodulator.

demonstrated the use of a "suitcase" terminal for the 30/20 GHz Satcom band [3] and is currently developing MMICs and planar antennas in order to reduce the overall size and weight of the terminal.

The Ka/K-band suitcase terminal uses direct modulation for the transmitter, and a direct downconversion receiver in an effort to reduce the number of MMIC components. The direct I & Q modulator [4] has about 9 dB conversion loss at 29.5 GHz and is used with a novel signal processing technique to suppress the carrier feedthrough [5]. The direct demodulator MMIC [6] occupies an area of 21mm^2 and is shown in Figure 3. The chip operates over an input frequency of 19.2 to 20.2 GHz and the I & Q output covers from DC to 200 MHz. The MMIC circuit was fabricated on a 100 μm thick GaAs substrate with a 0.18 μm gate low-noise PHEMT process. The receiver block diagram is shown in Figure 4 and illustrates how the MMIC is composed of two identical downconverters, a 90° hybrid coupler and a Wilkinson power divider. Each downconverter uses a single-balanced diode mixer integrated with a novel, miniature, microstrip 180° hybrid coupler (rat-race) ensuring that the LO drives the pair of planar PHEMT diodes 180° out of phase. An LO power of 15 dBm was used to drive the MMIC and the measured conversion loss is 11.45 dB ± 0.85 dB over the full 19.2 - 20.2 GHz (with a fixed IF of 50 MHz). The quadrature phase error is less than 4° while the amplitude imbalance between the I & Q ports is under 0.7 dB.

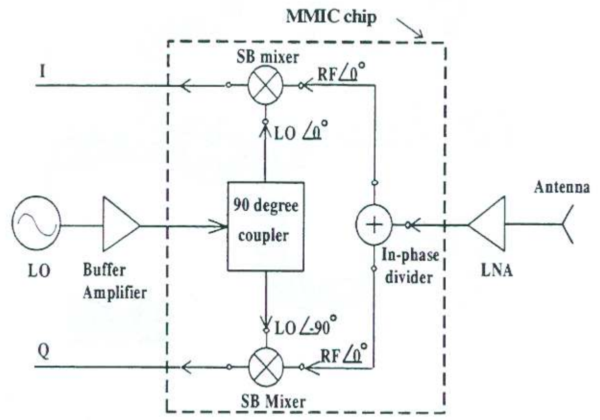


Figure 4. Block diagram of the I & Q Demodulator.

Figure 5. 30 GHz, 1 Watt, PHEMT power amplifier module developed by ITS Electronics Inc.

Figure 6a.

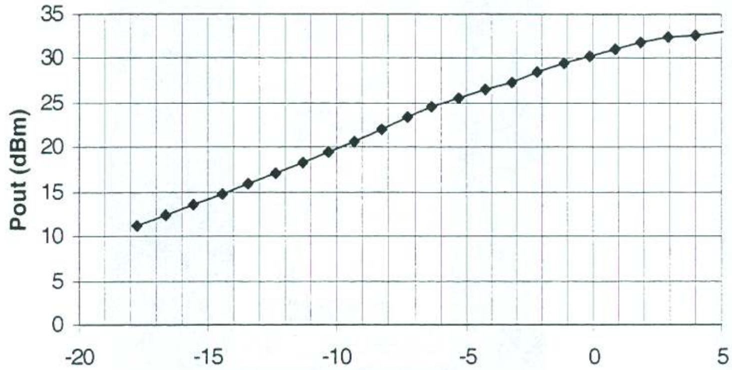


Figure 6b.

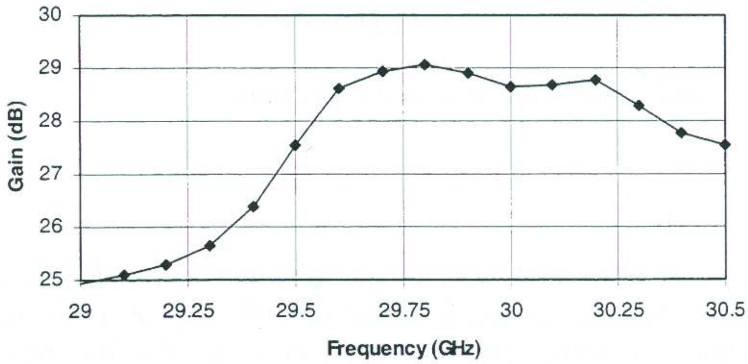


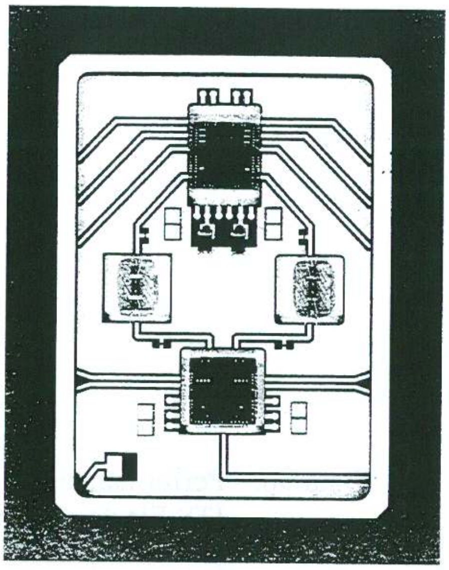
Figure 6. Performance of 1 Watt, ITS Electronics Inc. power amplifier (a) 30 GHz output power, (b) gain.

ITS Electronics Inc. has developed a 30 GHz power amplifier module using chips similar to those described in the terrestrial wireless communications section above. The module has about 29 dB gain and is intended for EHF Satcom earth terminals. Figure 5 shows the completed module and Figures 6a and 6b show the output power response and passband response respectively.

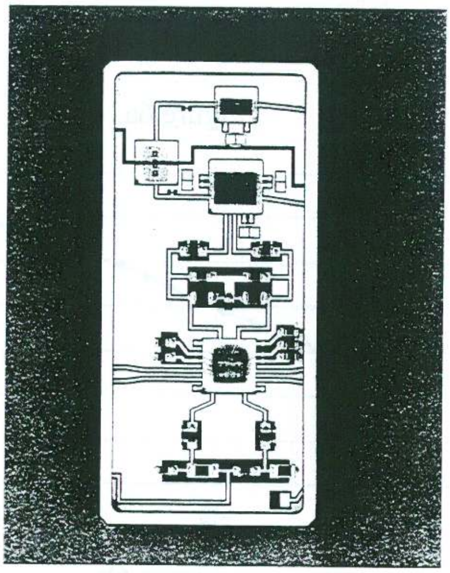
CELLULAR COMMUNICATIONS

Nortel's GaAs FET fabrication capability is located in Ottawa and is a 0.8 μm self aligned gate (SAG), ion implanted process producing FETs with cut-off frequencies of 20 GHz. To satisfy the exploding market in cellular telephone communications, Nortel has used their GaAs process to develop 275 000 modules of their TRU-2, dual mode radio system operating at 825 - 850 MHz. The receiver module (Figure 7a) has two identical chains for diversity and consists of a dual 3 to 1 antenna selector switch, associated control logic and dual low noise amplifiers on a single GaAs chip. Two double-balanced mixers with dual LO buffers are combined on a second GaAs chip. Both chips are connected through two lithium niobate SAW filters.

The transmitter module, shown in Figure 7b, uses a GaAs power amplifier chip for good linearity to produce 23 dBm (@ 1-dB compression) together with two Si chips to upconvert the 85 MHz IF signal to the 869 to 895 MHz operational band. A lithium niobate SAW filter is included to prevent LO and image frequency feedthrough. Both modules are fabricated on multi-layer ceramic substrates to aid testing and increase production yield.



(a) Receiver



(b) Transmitter

Figure 7. Nortel's TRU-2 dual mode radio system RF modules.

OPTICAL COMMUNICATIONS

Nortel's GaAs HBT process offers devices fabricated with GaInP emitters and with cut-off frequencies in excess of 60 GHz [7]. They have developed a complete HBT chip set for a high speed, OC-192, optical fibre communications system. The transmitter consists of a multiplexer chip, which combines eight 1.2 Gb/s channels into a 10 Gb/s bitstream with 4 W power dissipation, and a modulator driver chip providing either single-ended or differential outputs to drive an external modulator. Two versions of the modulator have been developed for either 5 V or 3 V operation. Three HBT chips are used for the receiver, a transimpedance amplifier for use with a PIN photodetector, a differential AGC amplifier providing between 20 and 23 dB gain with 1.0 V peak to peak output and a super demultiplexer chip providing the eight 1.2 Gb/s bitstreams. The demultiplexer chip also contains a built-in clock recovery function.

WAVE DIVISION MULTIPLEXING (WDM)

CRC, Nortel and NRC are members of a research group aimed at demonstrating the application of wave division multiplexing to a fibre based communications network. The demonstrator originally consisted of the prototype development of an eight channel, SONET compatible, network access module operating at 2.48 GHz (OC-48) and at 1.54 μm. The demonstrator has since been reduced to four channels. Figure 8 illustrates the WDM concept in which multiple data streams (in this case eight) drive an array of individual lasers. Each laser operates at a different wavelength and the resulting eight optical carriers are introduced into the WDM network by combining them onto a single

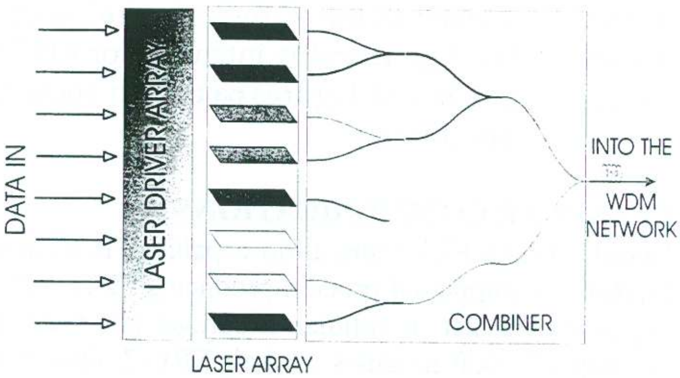


Figure 8. Multiple channel combination in a WDM transmitter.

optical fibre. CRC was responsible for developing the GaAs ICs and for the module integration and packaging. Figure 9 shows the integrated transmitter in which eight RF coplanar feed lines supply the signals to the laser array, the single fibre output can be seen at the bottom of the picture. The receiver uses two HBT based chips to realize a four channel system. The first chip contains a transimpedance amplifier and a differential amplifier. The second chip contains another differential amplifier and an output buffer. The total gain from the two chips is approximately 90 dB between 8 kHz and 2.5 GHz.

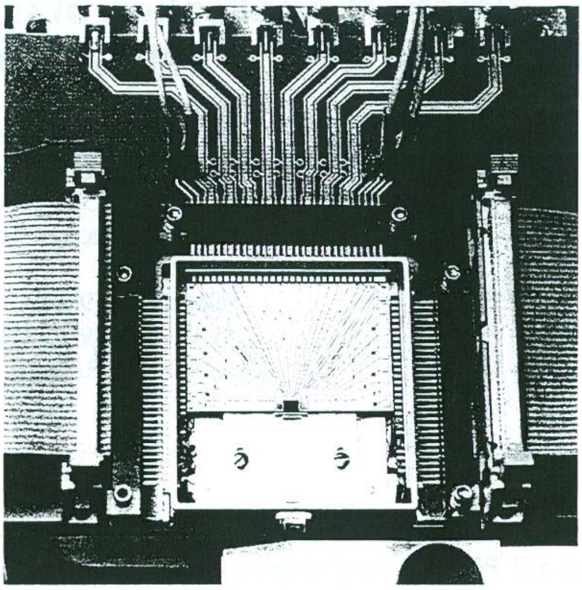


Figure 9. WDM transmitter showing the 8 channel input.

CONCLUSIONS

This article describes some of the current activities in GaAs IC technology in Canada. Wireless applications are a rapidly growing area and LMCS systems at 28 GHz are being developed for deployment. Experimental, portable satellite communications terminals are also being developed and the miniature characteristics of GaAs MMICs have a significant role to play here. Finally, GaAs technology is also being exploited in optical networks with HBTs playing an important role.

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