Active Quasi-Optics

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There has been terrific progress in high-speed transistor technology, and this makes it possible to construct transistor amplifiers now for frequencies as high as 220GHz. However, the output power drops rapidly at the high frequencies for fundamental reasons. The gate length must be made short to make the transistor fast, and this limits the voltage. The gate width must scale with the length to maintain reasonable impedance, and this limits the current. The result is that the maximum power tends to drop off as frequency squared. Transistors produce hundreds of watts at 30MHz, but only a few milliwatts at 30GHz. This limits the introduction of millimeter-wave radars, high-speed point-to-point Internet connections, and high-speed millimeter-wave satellite uplinks. For these transmitters, we need to be able to combine the outputs of hundreds or thousands of transistors. However, the traditional transmission-line power combining technology using Wilkinson splitters and combiners is limited by transmission-line losses. Power loss on transmission lines follows an exponential law with distance, and that means that there is a maximum output power that can be achieved; adding more devices actually reduces the total power. Power combiners based on Wilkinson couplers typically have only 8 or 16 devices.

At Caltech, we have been studying power amplifiers based on spatial splitting and combining. The advantage of this approach is that the outputs of large numbers of transistors can be combined with low loss. We make periodic structures loaded with transistors that are called *grid amplifiers.* These are made as single gallium-arsenide integrated circuits with up to 500 transistors. The input is a beam that comes through the back of the chip, and the output comes out from the front. We measured a combining loss of only 1-dB for a 35-GHz grid amplifier. The output power was 5W. Early measurements were made with large 30-cm diameter plastic lenses, which are not suitable for applications outside of the laboratory, but recently we have developed compact waveguide mode converters for coupling to the grid amplifier [1]. In addition, we have built an indium-phosphide grid amplifier in waveguide that operates at 60GHz, but with a small 2-dB gain [2].

References

[1] "A Waveguide Mode-Converter Feed for a 5-W, 34-GHz Grid Amplifier," Chun-Tung Cheung, Jonathan B. Hacker, Gabor Nagy, David Rutledge, International Microwave Symposium, Seattle, June 2002.
[2] "V-Band Transmission and Reflection Grid Amplifier Packaged in Waveguide," Chun-Tung Cheung, Roger Tsai, Reynold Kagiwada, David Rutledge, submitted to the International Microwave Symposium, Philadelphia, June 2003.

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