New Applications in Commercial Remote Sensing Enabled by Recent Advancements in Millimeter-wave Technology and Sensors

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1. INTRODUCTION

Over the last two decades, microwave remote sensing observations have become an integral part of society's daily and long-term decision-making. An individual may glance at the latest NEXRAD imagery on his/her computer, cell phone or television to decide if a storm is close enough to warrant bringing an umbrella before travelling to the local store. Recreational and commercial marine vessels rely on microwave marine surveillance radars to see through the fog and weather to detect navigation hazardous. Scientists and forecasters use satellite-based microwave remote sensing measurements of the mean ocean sea level and oceans surface vector winds to estimate ocean heat content and further our understanding of tropical cyclone formation and intensification[1][2]. This has led the commercial sectors within the remote sensing field to develop a spectrum of products from radar systems to data analysis tools to value added packaged products focused on microwave remote sensing applications. However, due to practical size, weight and power constraints, microwave radar systems do not provide the optimal solution for many applications.

With antenna apertures at a fraction of the size of their microwave counterparts, millimeter-wave radar systems can provide unique and cost effective solutions where space constraints and resolution requirements prohibit the use of microwave radar systems. A prime example is in the automotive industry. Today, car companies are now rolling out vehicles with millimeter-wave radars that are used in providing blind spot detection and automatic cruise control systems that detect other vehicles and hazards that are hundreds of feet away and that pose a potential threat. Yet such systems are still have limited range with respect to broader environmental and weather remote sensing applications. However, recent advances in millimeter-wave power amplifier technology driven by the communication industry are enabling the use of millimeter-wave radars for longer range applications. This paper will describe current state of Ka-band power technology, the advantages it provides and the unique problems that can be address in the commercial sectors.

2. Advancements in Ka-band Technology

Traditionally, Ka-band radar systems have relied on high peak power Ka-band transmitters to provide adequate sensitivity for medium to long range applications, such as atmospheric remote sensing and high resolution mapping. For such applications, extended interaction klystron (EIK) amplifiers are often employed. These amplifiers offer 800 W to 1.5 KW peak transmit power levels, and 3 KW peak power systems are under development. Depending on the application's resolution, sensitivity and aperture requirements, this nominally translates to range coverage on the order of a few kilometers to tens of kilometers. However, these systems have significant limitations. First, they operate with very high supply voltages, which reduces their overall reliability and requires pressurization for most airborne applications. Second their duty cycles and pulse width are limited resulting in their effective average power being less than 2 percent for air cooled systems and less than 10 percent for liquid-cooled systems. This prohibits the use of more complex waveforms that can improve the overall sensitivity and measurement precision through the use of waveform encoding and frequency agility. Another hurdle is the cost. When taking into account the amplifier, modulator and the cost for higher peak power front-end components, the overall financial impact can be on the order of \$100K to \$150K more than a solid-state system. Longer lead times for these componentry can also have a cost impact of the fabrication process and the need to stock back up units for high availability applications.

Solid-state power amplifiers offer an attractive alternative. Recent advancements in solid-state Ka-band power modules have led to the development of commercial Ka-band power amplifiers that achieve peak and average transmit power levels of 10W to 100W. Figure 1 compares the average available transmit power of a cooled 100W solid-state power amplifier to a liquid-cooled 1.5 KW, 10 percent duty EIK amplifier. Although to operate at 100% duty cycle a FMCW design would be required, advancements in transmit waveform designs enable single aperture systems to utilize more than 70 percent of their pulse repetition period without suffering blind regions.[3] As this figure shows, the available power from solid-state Ka-band amplifier is constant with range (i.e. does not have pulse width limitations) and falls within 1.8 dB of the EIK amplifier for short-range applications. For long-range applications (i.e. low pulse repetition frequency), the solid-state solution can provide significantly higher average power levels.

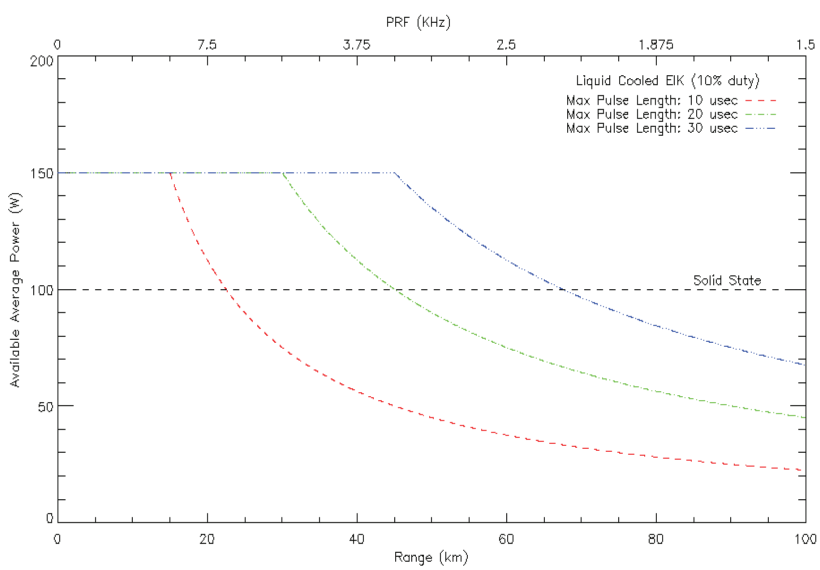

Figure 1: Available average transmit power level of a 100W solid-state power amplifier (black dashed line) and a 1.5 KW EIK amplifier with 10% duty cycle and maximum pulse widths of 10, 20 and 30 usecs is plotted versus range (i.e. PRF).

Further, solid-state amplifiers operate with very low supply voltages (less then 10VDC). This allows the system to operate unpressurized even at altitudes as high as 70,000 feet. The low voltage also makes it possible to build very fast switches (10 to 100 nsec) that can turn the final power stages off when not transmitting thereby reducing the average current consumption. And with low operating voltages and parallel power combining structure, the MTBF of these amplifiers can exceed 300,000 hours. Combining these features with their small low profile design and low costs (commercial units providing over 50 W output power are priced under $30K), make solid-state amplifiers very attractable for commercial applications.

3. Applications

The advancements in Ka-band solid-state amplifiers have enabled the use of Ka-band radar systems for applications typically reserved for microwave radars or infrared and optical systems. This paper will present several new and exciting opportunities from atmospheric radar systems to search and rescue applications to ultra high resolution mapping systems to electronic vision systems.

References

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