The use of COTs MMIC’s in a Ka Band Radar System.

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Abstract
This paper concerns the design of a Ka band up-converter sub-system developed for use in a commercial radar system. The function of the unit is to combine S and J-band input signals to produce a Ka band output of 13dBm. The component parts detailed here include a divider circuit, J band amplifier, frequency doubler and Ka band amplifier. A previous design of this up-converter used discrete semiconductor devices many of which are no longer available due to obsolescence. The current design described here, makes use of commercial off the shelf MMIC technology which has resulted in an up-converter which has equal performance to the original as well as being considerably easier to manufacture.

Up-converter Block Diagram
The sub-system block diagram is shown in Figure 1. The system operates as an up-converter for a Ka-band radar system. Elements of the system (shown in Green) have been re-developed in order to reduce costs, improve reliability, reduce power consumption and overcome device obsolescence issues.

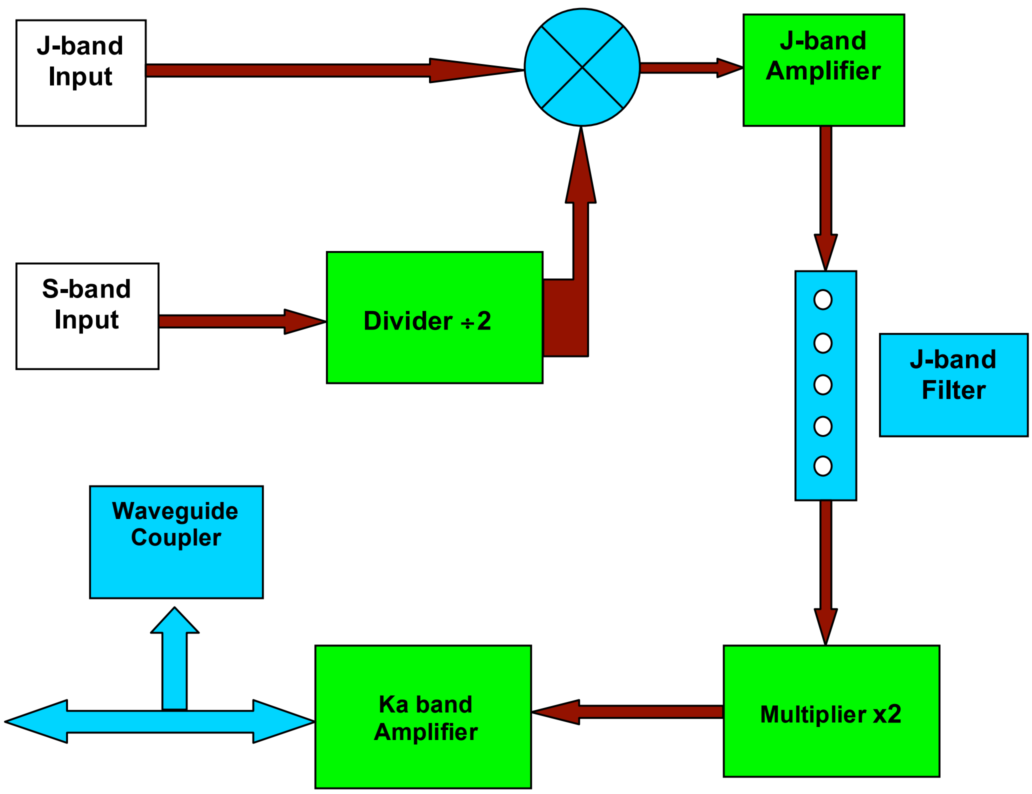


Figure 1: System Block Diagram showing components re-developed using COT’s MMIC Technology.

Divider
This unit provides a divide-by 2 function on the applied the S-band input.

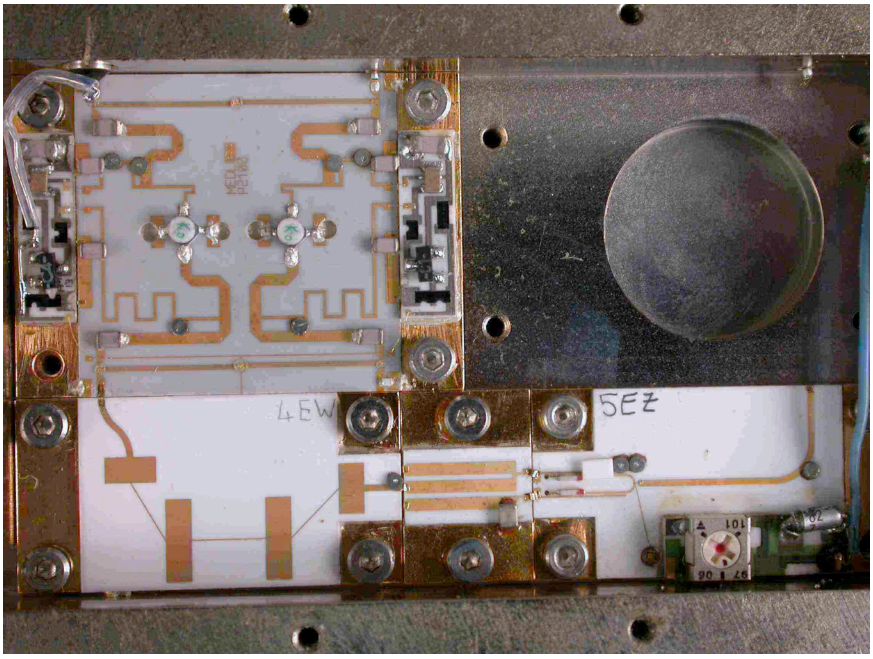


Figure 2 – Original S-band divider circuit

The original circuit design is shown above. The circuit was constructed using alumina thin film microstrip circuits mounted on gold plated titanium carriers and these required several hours to assemble and align correctly.

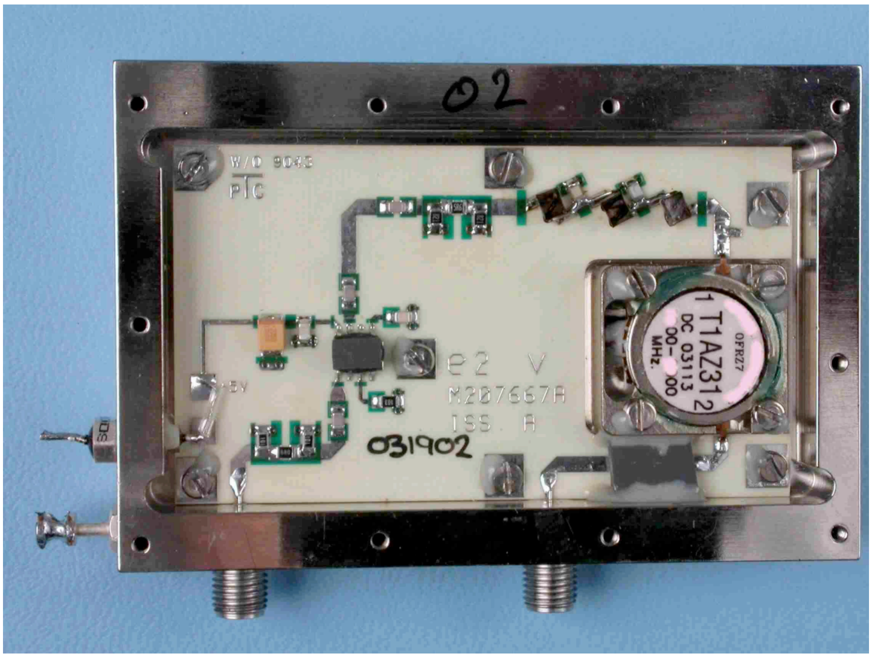


Figure 3 – New S-band divider circuit

The new divider makes use of a commercial digital divider and microstrip circuitry on soft-board. A drop-in isolator was used at the output of the device to ensure a good match across the frequency band of operation and a low pass filter was included to attenuate the input frequency component. The unit required no alignment and operator assembly time was considerably reduced. The performance of the unit is shown in figure 4. A 4GHz input signal is shown together with the divided output.

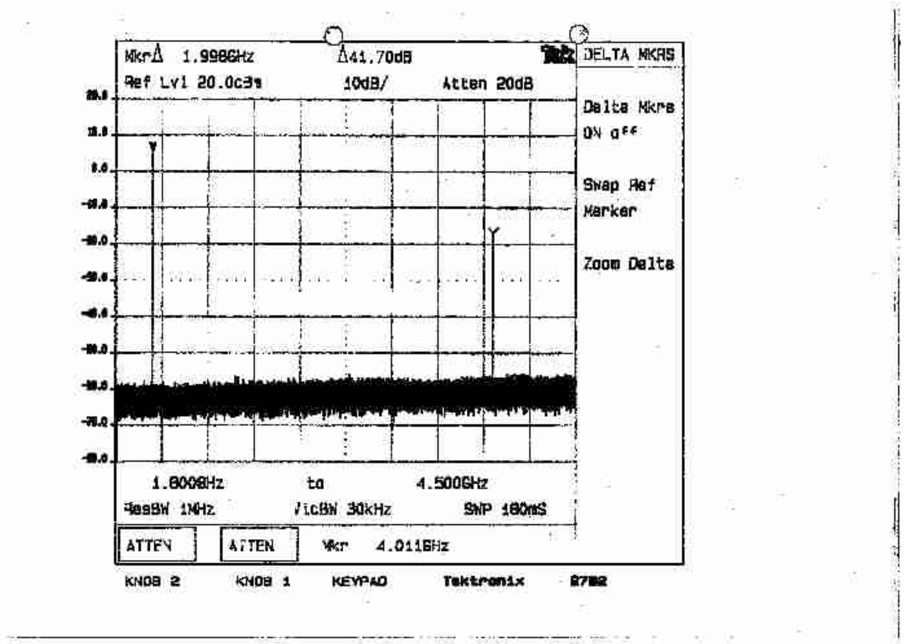


Figure 4: Typical output spectrum from the divider unit.

Mixer
A discrete standard e2v mixer design solution is to be continued to be used for this component, as the part is a current production item.

J band amplifier
The original amplifier was a 7 stage chip and wire design as shown in figure 5. An output power of ~25dBm was required in order to drive the original frequency doubler.

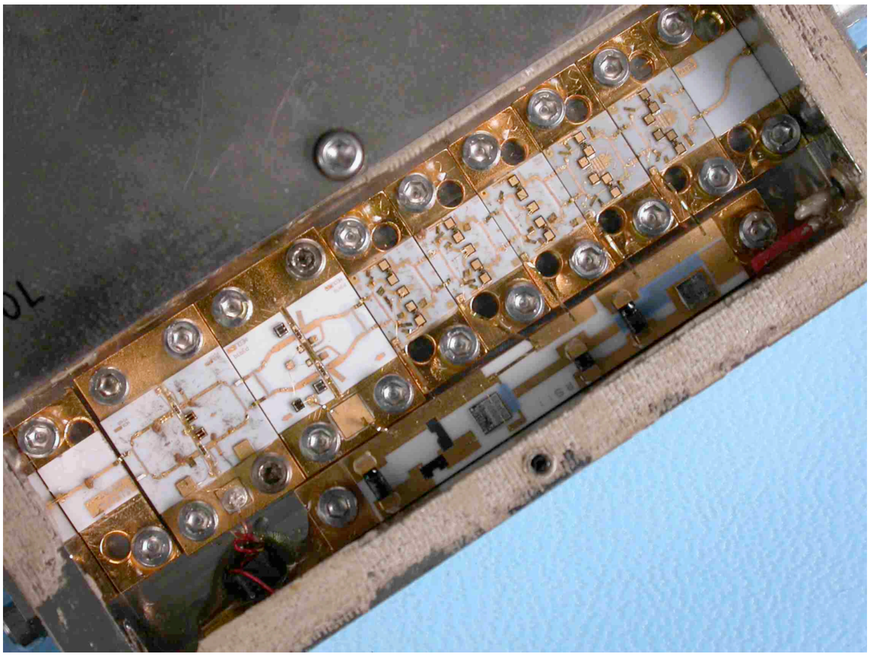


Figure 5: Original J-band multi-stage amplifier

In the new unit, a 2 stage amplifier MMIC chip was used together with alumina MIC feed lines as shown in Figure X. The amplifier was designed to operate with a saturated output to provide a level input power to the frequency doubler/Ka-band amplifier.
A drop-in isolator placed at the output of the amplifier, ensured a good match on the output port. The result was that only limited tuning was required to obtain the specified input match and flat output power over frequency.

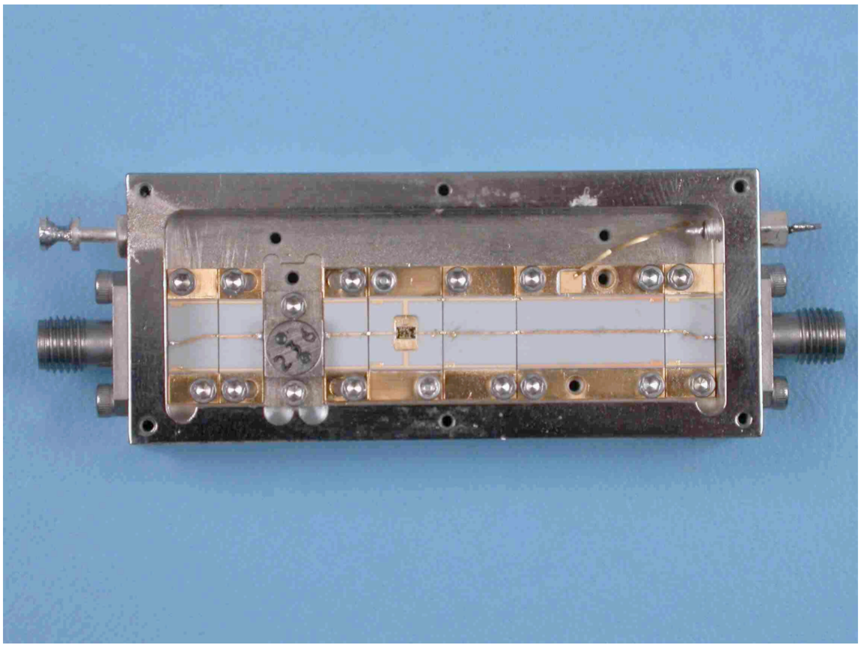


Figure 6: Up-dated MMIC J-band amplifier

In figure 6 it can be seen that the complexity of the amplifier is greatly reduced and it is also apparent that the unit could have been made much smaller if form, fit and function had not been a requirement of the new device. The data sheet provided by the manufacturer for the MMIC gave little information as regards its performance over temperature when operated in saturated mode. As a consequence the unit had to be characterised for operation in this mode.
Figure 7 shows the saturated output power to be ~12.5dBm and this is flat as a function of frequency over a 1.5GHz band. Figure 8 shows the output power variation over the specified temperature range of -45°C to +80°C.
The required output power from the new device was much lower than that from the earlier units since it was driving a doubler device and amplifier which had gain rather than a 10dB conversion loss.

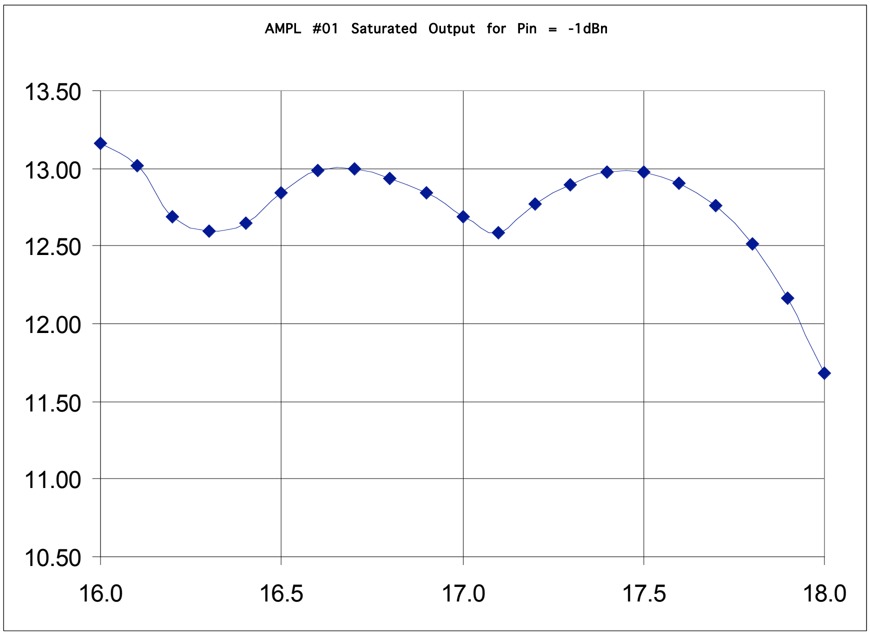


Figure 7: Power output vs Frequency for J-band amplifier

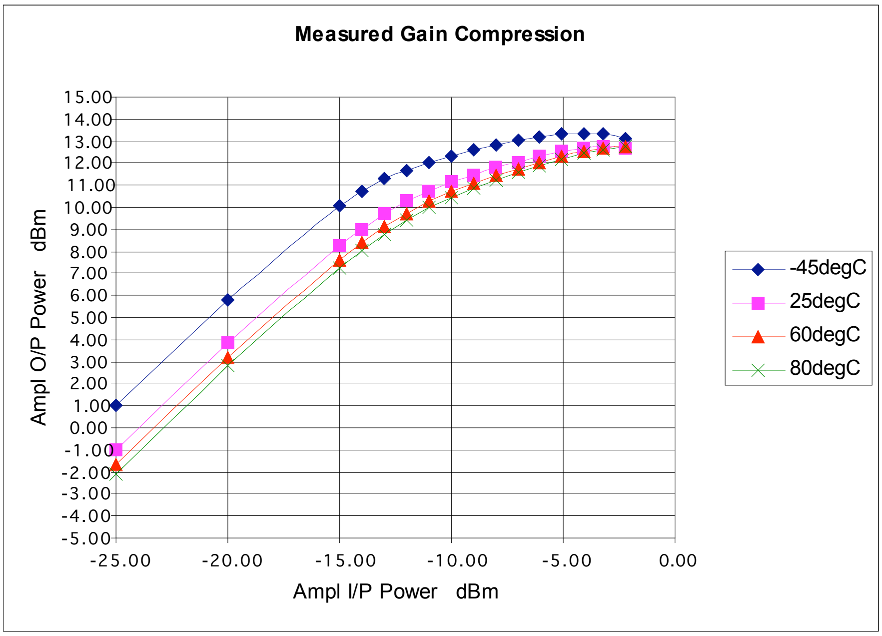


Figure 8: Power output vs Temperature for J-band amplifier

Frequency Doubler and Ka Band Amplifier

The original frequency doubler circuit was a waveguide device and had a conversion loss of 10dB, which required a J-band drive level of around 25dBm in order to achieve the required Ka-band output of 16dBm.
The final frequency doubling and amplification in the new components was accomplished using a MMIC doubler to convert the J-band input signal to a Ka band output signal followed by a 4-stage MMIC amplifier chip to provide the final stage amplification. A hybrid coupler was fabricated on the output tile to sample the power output; this power fed a detector diode, which was used to provide a simple level detection bite function.

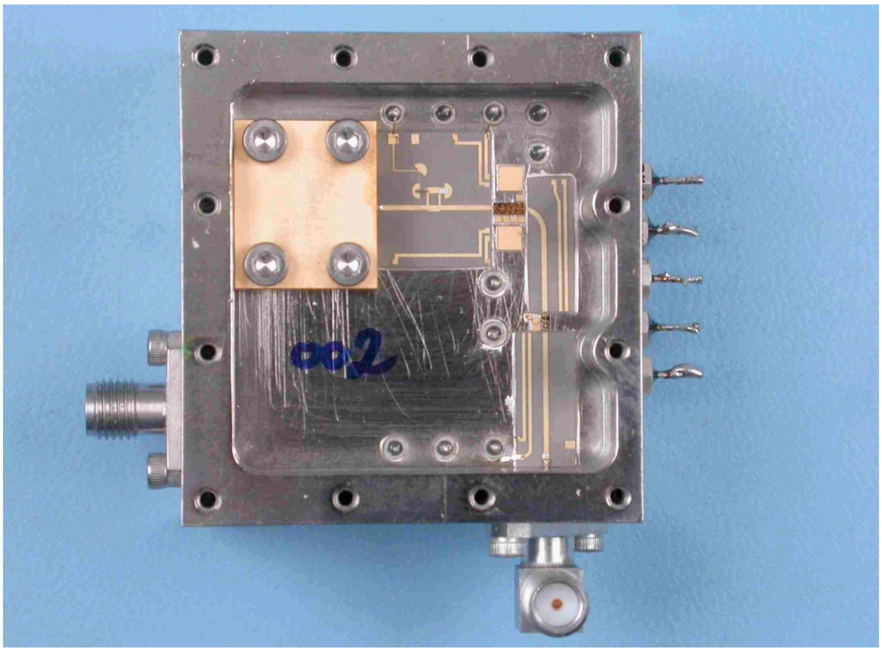


Figure 9: Doubler/Amplifier unit RF layout

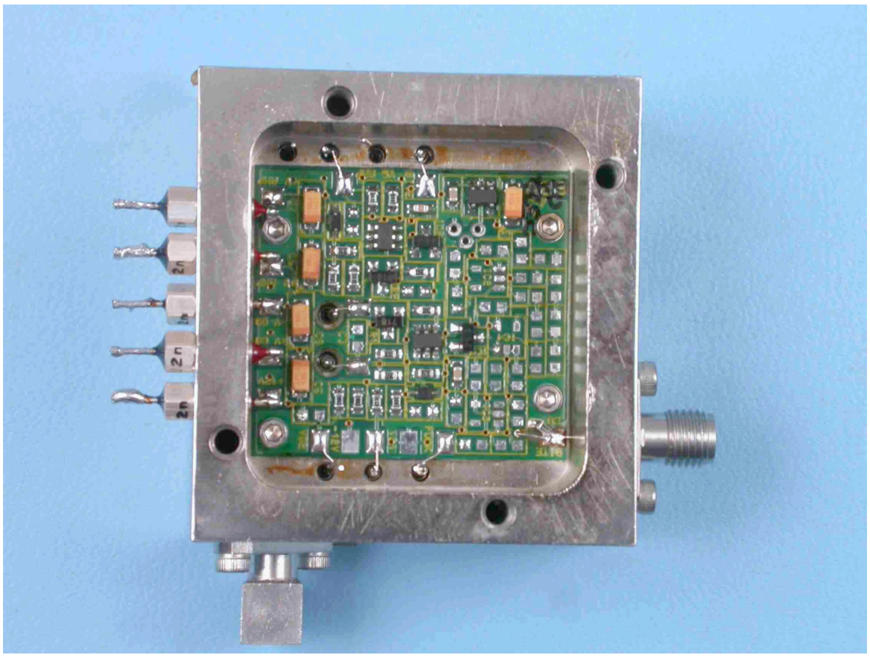


Figure 10: Doubler/Amplifier unit Bite/DC layout

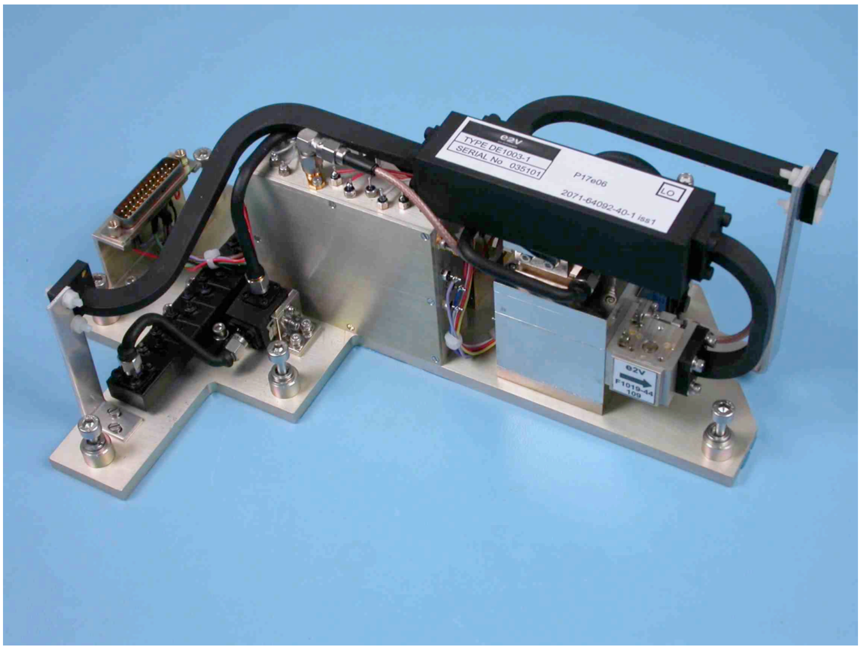
The output of the amplifier was transformed from microstrip to a Ka-band waveguide via a step-ridge transition. The waveguide aperture in the housing was sealed with a waveguide window to prevent the ingress of moisture when the unit was mounted in the final radar system. The microwave integrated circuits in this component were fabricated using thin film Z-cut quartz substrates mounted directly to the housing floor.

As with the J-band amplifier, the manufacturer's data sheets provided for the doubler and Ka-band amplifier MMIC's did not provide adequate information for operating the devices in a variety of modes or temperature ranges. As a result a testing sequence was derived to gain information on the MMIC's under pulsed operation over a variety of input power levels and temperature ranges.

System Screening
The assembled components were subject to a screening procedure which included the following:

The final assembly was stored at a temperature of +85°C for 160 hours with DC bias and RF input signals present, this elevated burn-in aims to stress semi-conductor components and force failures in any components that may be weak or damaged.
The device was also subjected to 24 hours of temperature cycling between -40°C and +85°C at a rate of 1°C/min. Finally the unit was subject to a random vibration from 20Hz to 2KHz for a duration of 10 minutes in each axis.
The device was then tested and inspected for any signs of electrical and mechanical failure.
This testing helped identify that some MMIC's suffered from an initial drop in the output power level when burnt in under DC and RF power, however this was observed to stabilise after a few days of soak testing at +85°C.

Final System Results
The new components were assembled together with the bought-in parts to form the final assembly as shown in Figure 11.



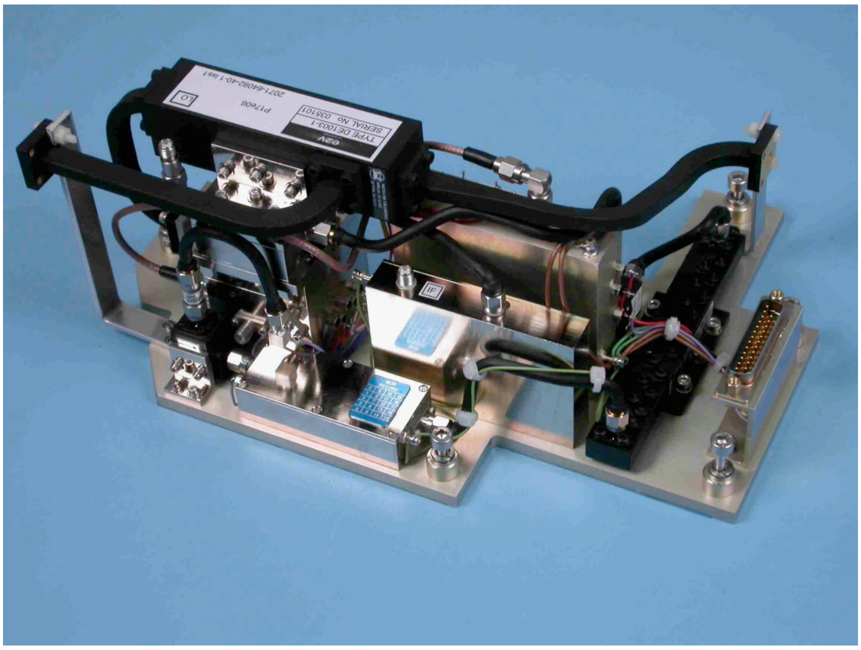


Figure 11

The completed sub-system is required to produce a level Ka-band output power of 13dBm within a +/-1dB window over a bandwidth of 1400MHz over the temperature range of -40°C to +85°C. This was achieved and Figure 12 shows the final Ka-band output for the unit over temperature.

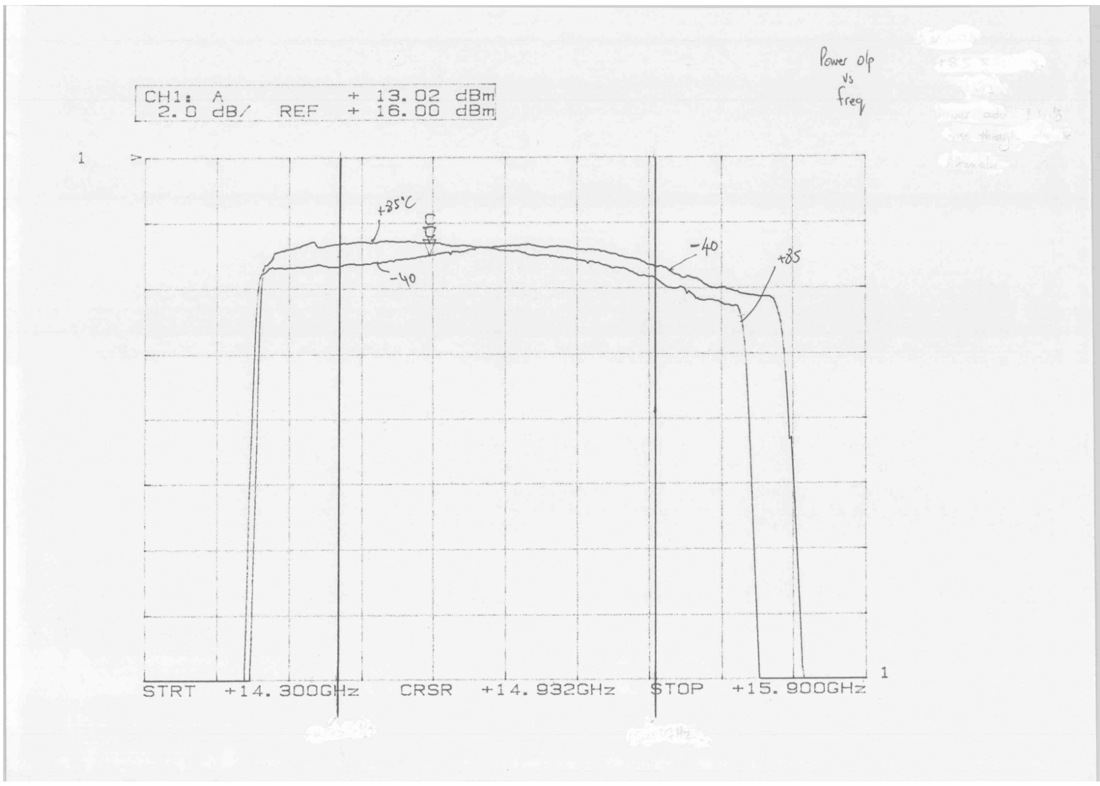


Figure 12: System output power variation with temperature.

Conclusion

The use of Commercial of the shelf MMIC’s has been demonstrated for use in a Ka band radar system. The components developed using these parts have been easier to assemble, align, test and also consumed much less power when compared to the original parts whilst giving comparable performance. The obsolescence issues encountered when requested to manufacture units to the original design have now also been resolved.