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EXTENDED RANGE COVERAGE OF AN IMAGING RADAR SYSTEM WITH FEED-MOUNTED 94 GHZ MIMIC HEMT LOW NOISE AMPLIFIER AND EXTERNAL ILO

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Abstract

Low transmitted power and high noise figure of a homodyne FMCW front-end limit range coverage of 94 GHz imaging radars to less than 1000 meters. Using a combination of 2-stage MIMIC, 94 GHz HEMT low noise amplifier and external ILO mounted at the feed locations, the improved imaging radar can produce visible runway images up to 3,000 meters away. The very first FMCW runway images are shown to demonstrate the 94 GHz system resolution; additional images will be presented for adverse weather conditions. This is the first time low noise MIMIC technology is being used in a high potential, 94 GHz commercial airborne radar system.

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An airborne forward-looking radar has been developed and built to provide an image of an airport runway for a pilot who is landing his aircraft in zero (or low) visibility fog (Figure 1). Because of the requirement for high azimuth resolution in the HUD-displayed radar image from a small-sized antenna (24 inches max. diameter), 94 GHz was selected as the RF frequency. The image contrast depends on the radar backscattering difference between the runway and the adjacent grass background. Figure 2 shows the calculated S/N and S/C vs. range at 94 GHz.

In order to maximize the runway recognition range, a low receiver noise figure is needed. Using the combination of a MIMIC low noise HEMT amplifier and an external ILO mounted behind the feed horns, runway images are visible up to 3,000 meters. This is the first time a 94 GHz low noise HEMT amplifier has been used in an active airborne radar system for commercial application.

From the classical radar range equation, the radar range increases with higher transmitted power and/or lower receiver noise figure. At 94 GHz, higher transmitted power is very expensive by using a multiple cavity combiner. The simple dual IMPATT power combiner can provide at most a 3 dB improvement. Another alternative is to reduce the receiver noise figure by using a low noise amplifier. This is a viable approach with the advances of low noise MIMIC technology at 94 GHz. Two-stage MIMIC HEMT low noise amplifiers exhibit typically a noise figure of 6 dB max. The bistatic antenna unit is modified to accommodate a 94 GHz LNA and an IMPATT ILO at the feed locations. With these modifications, the transmitter loss reduces to a minimum, and the LNA noise figure dictates the total receiver noise figure. The final transmitted power is increased from 150 mW to 340 mW, and the total receiver noise figure is reduced to less than 10 dB. Figure 3 shows details of the modifications at the antenna feed horns where the LNA and ILO are mounted. A complete block diagram of the improved radar system is shown in Figure 4.

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The radar system has been tested in several locations (LAX, small airport, and local highway). However, the test locations are not realistic representations of the real scenario of a landing aircraft. Figures 5 to 7 present the very first FMCW runway images at 94 GHz.

Figure 5 shows an image of a small runway at a short distance with the original radar system. In this case, the complete radar system is mounted on a flatbed truck, and the radar is only about 15 ft above the runway. Figure 6 is taken at Los Angeles International Airport (LAX). The radar is about 30 ft above the ground and at a 90-degree angle to the runways. Runway images are clearly visible to 800 meters away. At longer distances, runway images were not possible due to the limited height of the radar test setup. The images were taken with the original radar FMCW transceiver.

At the WPAFL tower, the radar is 75 meters above the distant runway, and the first visible runway portion is about 1500 meters away. The radar is at a 30-degree angle with respect to the 1500-meter-long runway. The original radar system can only produce a very faint image of the nearest portion. After retrofitting the radar with an external ILO and a low noise HEMT amplifier, the runway image was clearly more visible, as shown in Figure 7. Figure 7 also shows the runway photograph taken with a 35mm camera on the same day at the WPAFL tower. Figure 8 shows the Torrance airport 2000 meter long runway image, the radar is about 50 ft above the ground and located near one end of the runway.

In the next evaluation period, the radar will be used to collect the runway images under various weather conditions. Additional runway images under adverse weather conditions will be presented at the meeting.

CH3141-9/92/0000-0687$01.00 © 1992 IEEE

Improved 94 GHz Imaging Radar Parameters

Radar type	FMCW
Configuration	Bistatic/Homodyne
Center frequency	94.3 GHz
Transmitted power	340 mW
Noise figure	< 10 dB
Tx/Rx antenna isolation	65 dB min.
Antenna gain	39.5 dB
Polarization	Circular
Horizontal beamwidth	0.30°
Vertical beamwidth	2.8° (cosecant square beam spoiler)
Scan Rate	5 Hz

Improved 94 GHz Imaging Radar Parameters (Cont.)

Azimuth scan angle	± 15° or ± 30°
Elevation stabilization	± 15°
Bandwidth	CW/50/100/200 MHz
Sweep time	1.8 mS
Linearity	< 0.1%
Sub-ramp	4 per sweep
Display	C scope (elevation vs. azimuth)
Maximum process range	6,000 meters, Acquisition mode 3,000 meters, Approach mode 1,500 meters, Taxi mode
Range resolution	14 meters at 6,000 meter range 7 meters at 3,000 meter range 3.5 meters at 1,500 meter range

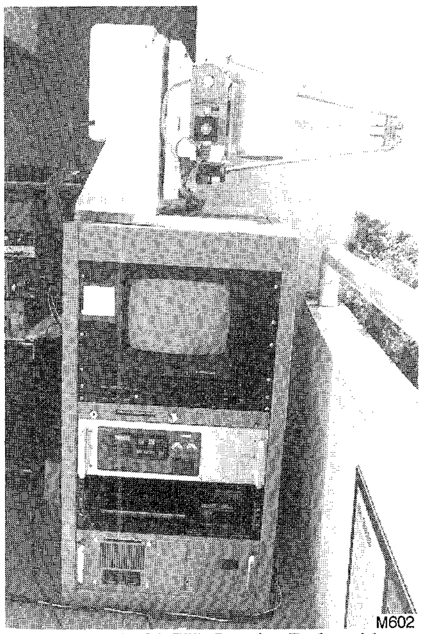


Figure 1. 94 GHz Imaging Radar with Data Collection System

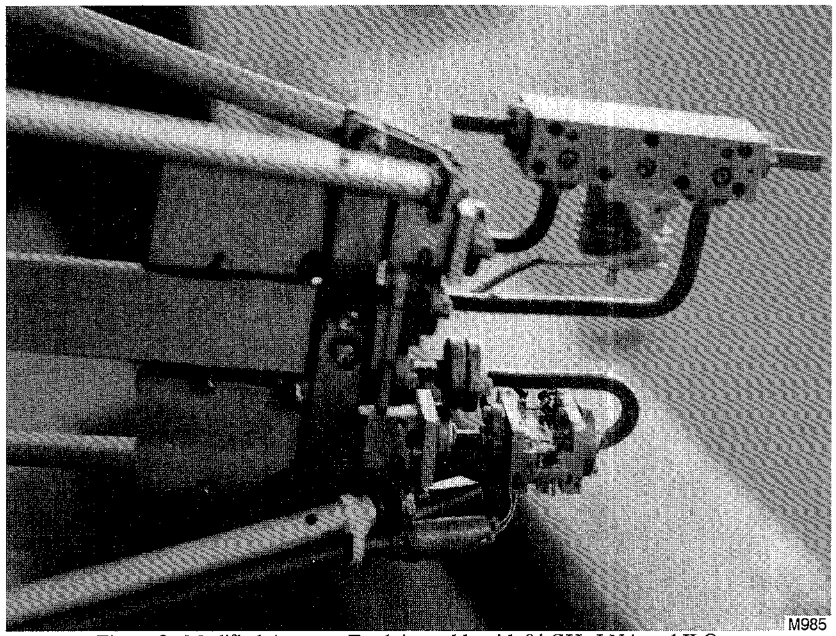
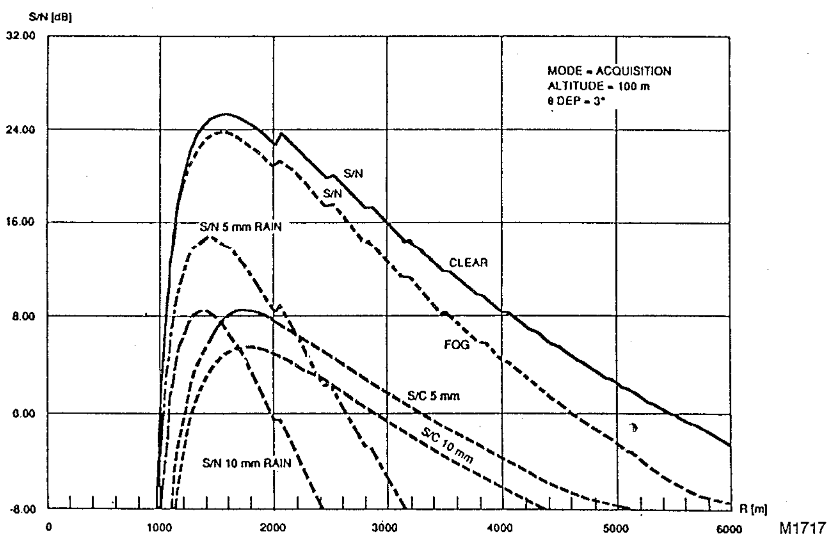


Figure 3. Modified Antenna Feed Assembly with 94 GHz LNA and ILO

Figure 2. Signal to Noise and Signal to Clutter vs Range



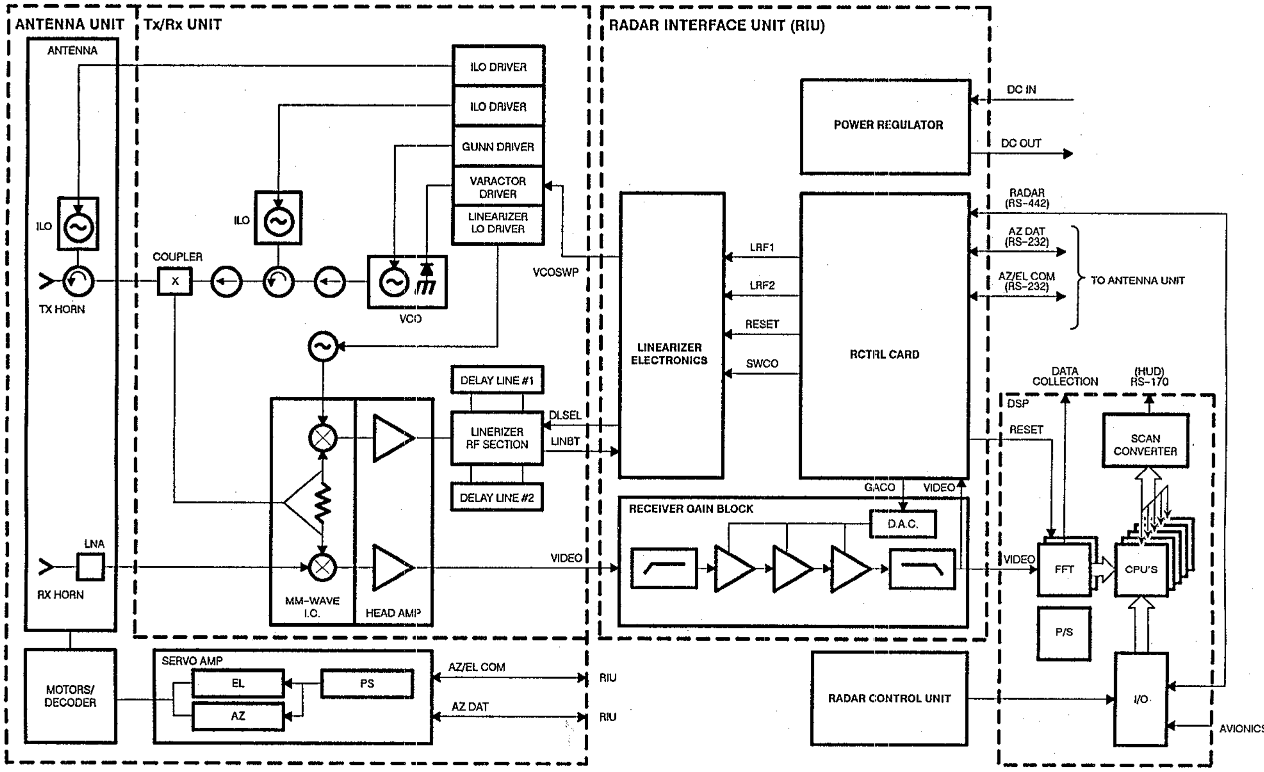


Figure 4. Detailed Block Diagram of the 94 GHz Imaging Radar

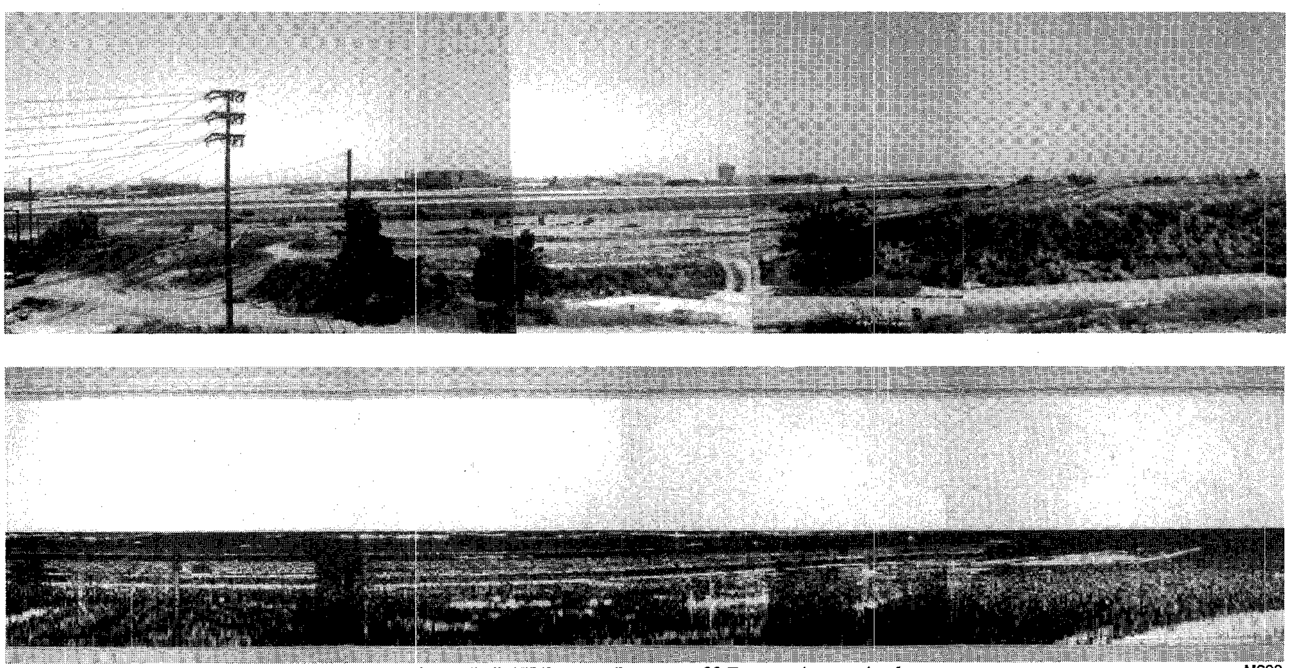


Figure 5. LAX Runway Images at 90 Degree Aspect Angle
(Visual Image vs C-Scope Radar Image)

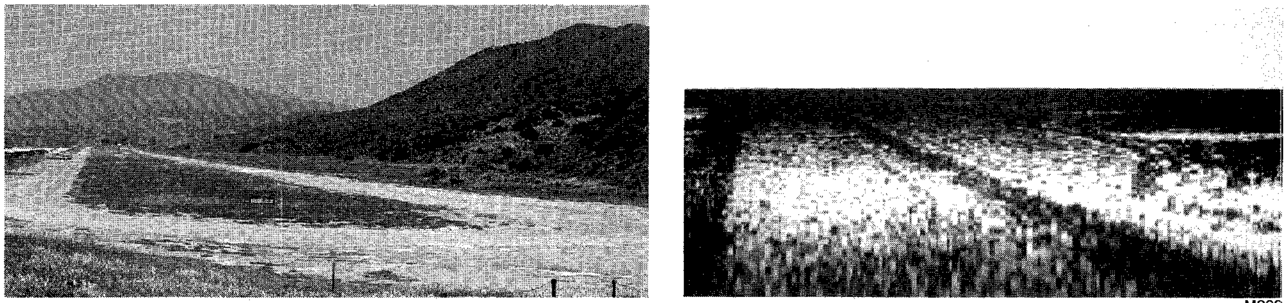


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Figure 6. Small Airport Runway at Short Distance
(Visual Image vs C-Scope Radar Image)

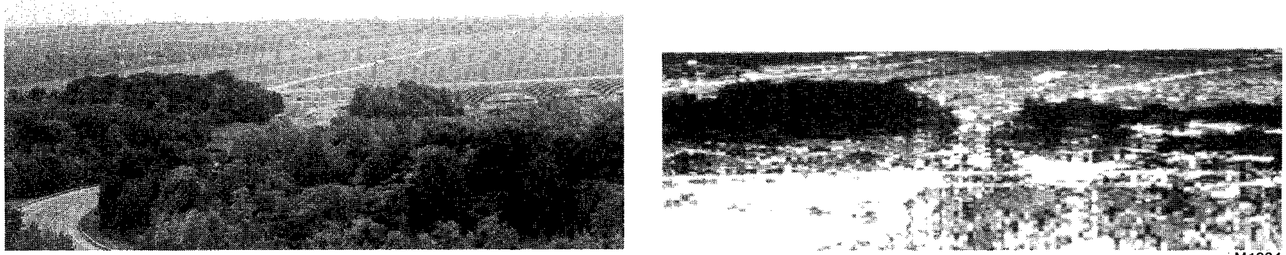

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Figure 7. WPAFB Image at 1500 Meters Away
(Visual Image vs C-Scope Radar Image)

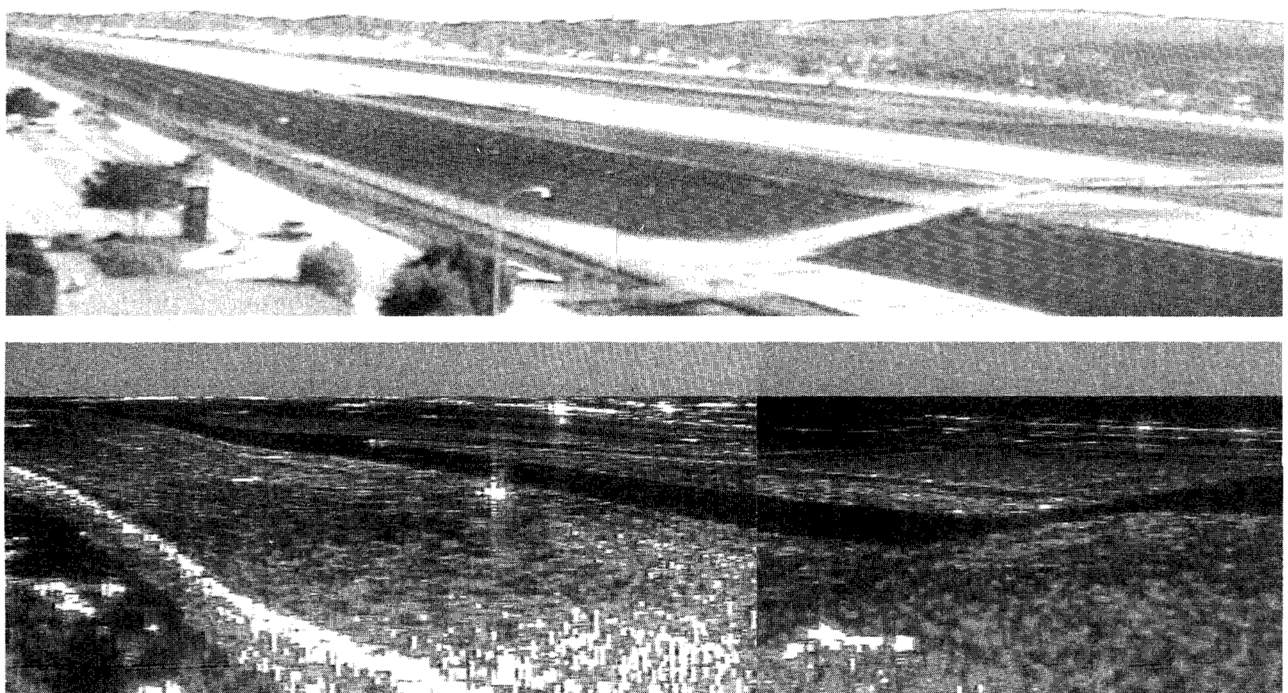

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Figure 8. Torrance Airport Runway Images
(Visual Image vs C-Scope Radar Image)