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94GHz INTEGRATED MONOPULSE RADAR DEMONSTRATOR

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SUMMARY

The design and development of a new miniaturised Monopulse Radar demonstrator is described. The construction of the front-end is illustrated and some experimental performance results are presented.

INTRODUCTION

The predicted worldwide requirements for smart munitions coupled with rapid advances over the past 8 years in the field of millimeter wave components and sub-systems at MEDL Lincoln have prompted the development of a direction sensing miniature, mass producible, fully integrated 94GHz Radar unit.

This submission is a concise summary of the radar's construction and operating principles. Fig. 1 shows a block diagram of the radar construction. The three main modules shown in Fig. 1 are discussed individually below following a brief outline of design aims for the unit.

DESIGN AIMS

The required electrical performance of the unit was dictated by the need to be able to demonstrate the radar to potential customers over a short range, (100 meters with 10m min range and a min range resolution of 10m) and using as little additional hardware as possible.

Mechanically, the unit should be as small and light as possible to enable its possible use in small dia (~ 4") munitions. e.g. shells.

FRONT END

The radar front end is subdivided into three main assemblies; the monopulse antenna, monopulse comparator/Local oscillator power splitter (LOPS) and a mixer-preamplifier assembly. Each is outlined below:

Monopulse Antenna

The antenna 3dB beamwidth was chosen at 3° to give reasonable sensitivity. To achieve this within the set mechanical constraints, a simple four horn monopulse antenna was designed at a centre frequency of 94GHz. To keep cost and weight to minimum, whilst maintaining the tight mechanical tolerances required, the horn assembly was manufactured in aluminium using 3 dimension vectored wire erosion techniques. The sum gain of the antenna was 29dB.

Monopulse comparator/LOPS

The comparator and LOPS are manufactured on a small aluminium disc approximately 3" dia.x ½". This assembly is fed via two oscillator input ports and four input ports from the horn assembly. Of the 7 outputs from the block to the mixer assembly three are resolved by the comparator (sum, Diff A_Z, Diff E_L), 3 by the LOPS (sum LO, A_Z-LO, E_L - LO). The remaining port feeds the transmit signal to the sum channel microstrip circulator (see below).

Comparator performance results are shown in Fig. 2. LOPS performance results are shown in Fig. 3. A view of the inside of the comparator/ LOPS block is shown in Fig. 4.

Radiation patterns for the comparator/horn assembly are shown in Fig. 5.

Mixers and Preamps

The configuration used in this block is an arrangement of 3 microstrip mixers and 3 preamplifiers in a plane perpendicular to the axis of the radar and to the feeds from the comparator/ LOPS assembly.

The transition from these outputs to the quartz microstrip mixer substrates is made via E-plane probe transitions. Adjustment of the probe transition backshorts enables adequate phase trimming to be accomplished.

Fig. 6 illustrates the layout of the mixer substrate. Fig. 7 shows a photograph of this typical circuit. It can be seen that each substrate contains one microstrip circulator, one single balanced mixer and 3 probe transitions in the case of the sum channel, 2 in the case of the difference channel (with the third input terminated with a load in this case).

The microstrip circulator used exhibits, when measured in isolation, an insertion loss of less than 1dB over a 2GHz bandwidth, with an isolation of greater than 20dB. The balanced mixer gives better than 4dB DSB noise figure.

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The exact duplication of each quartz microstrip substrate using photo-lithographic techniques ensures that the precise matching of each channel required in a detection sensing system of this type is achieved.

The mixer outputs (Σ, E_L, A_Z) are at an IF of 250MHz. These drive 3 preamplifiers, each realised using low noise packaged amplifier stages. This arrangement gives 30dB gain and 2.2dB Noise Figure over 100MHz bandwidth. The outputs from the preamplifiers drive the ranging and direction sensing modules.

SOURCES

The radar requires two signal sources, a local oscillator and a transmitter. Both of these devices are waveguide 2nd harmonic Gallium Arsenide GUNN oscillators (giving 100mW peak output power). The transmitter source is a fixed frequency pulsed GUNN oscillator whereas the LO source is a VCO (giving 20mW cw output power). A novel pulsing circuit is used to modulate the transmit source to keep frequency chirp to a minimum. The VCO is used as a local oscillator so that it can be temperature tracked to the transmitter, thus keeping a relatively stable IF.

Both oscillators are manufactured in a miniature form and both are connected to the 2 input ports on the comparator LOPS block via miniature waveguide isolators. A view of the oscillator/isolator units is shown in Fig. 8.

Marconi miniature waveguide flanges are used throughout to keep size to a minimum.

PROCESSING AND DISPLAY MODULES

This module was built solely for the purpose of displaying the radar output for customer demonstration and as such was kept as simple as possible. It consists of circuits to resolve and display ranging information and angular information in elevation and azimuth off the radar boresight.

The ranging circuit is shown in Fig. 9. A 15MHz master clock is used since each cycle corresponds to the time taken for a pulse to travel 10m to the target and 10m back. Digital counters record the number of cycles between transmitted and received pulses, thereby achieving range resolution in 10m steps. The p.r.f. (50kHz) is derived from the master clock and the counters are arranged to average over 10 pulses before the display is updated. The display is in the form of a bargraph.

Fig. 10 shows the elevation display circuit. It is driven by a voltage V which is proportional to the angular displacement of the target from boresight. A digital signal S, derived from a phase detector which compares the phase of the sum channel to that of one of the difference channels, indicates on which side of boresight the target lies. A similar circuit drives the azimuth display. The two displays are arranged in a "cross-wire" format.

ASSEMBLED RADAR

A simplified exploded view of the radar assembly is shown in Fig.11. The maximum dimensions of the final assembly without antenna, display and processing is 3" dia. x 2.75" in length. The final dimensions of the antenna are 1.75" diameter by 1.2" in length.

The power consumption of the radar demonstrator is 13.7W total. The radar has not yet been fully commissioned, however trials have commenced and full results will shortly be available.

CONCLUSIONS

A 94GHz integrated Monopulse Radar front-end has been developed, built and demonstrated using state of the art millimeter wave integration techniques in both waveguide and quartz microstrip technology. Small size (21 cu inches) and potentially high performance are exhibited by the unit which, coupled with the potential low cost in mass production make this unit ideal for "smart" munitions applications.

ACKNOWLEDGEMENTS

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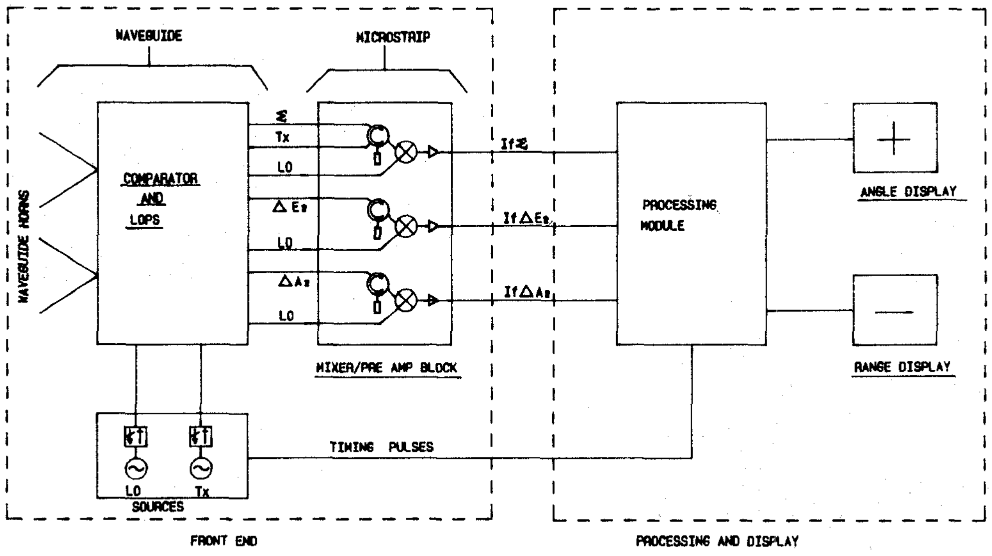

FIG. 1 : BLOCK DIAGRAM OF RADAR CONSTRUCTION

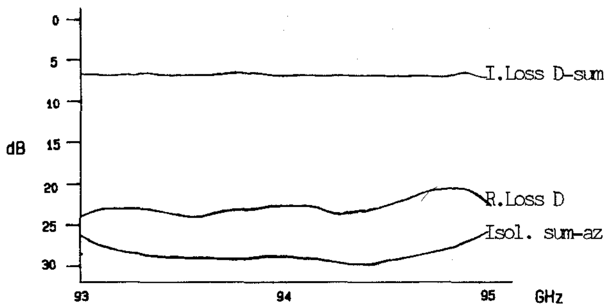

FIG. 2 COMPARATOR PERFORMAMCE

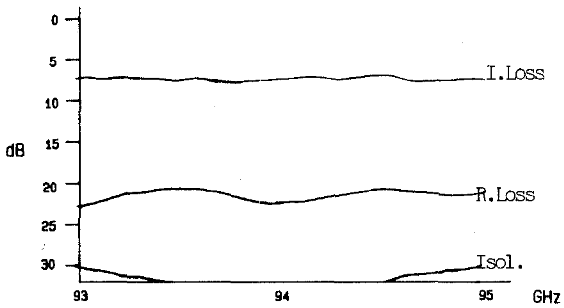

FIG.3 L.O.P.S. PERFORMANCE

FIG 4 COMPARATO‹. _.O.P.S. BLOCK

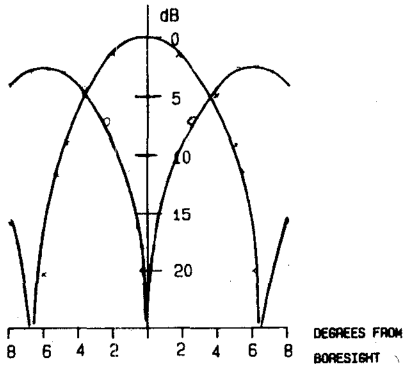

FIG.5. E-PLANE RADIATION PATTERNS.

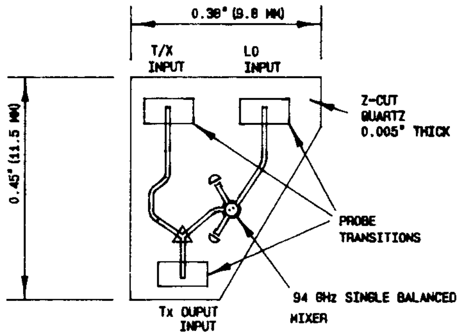

FIG 6. MIXER SUBSTRATE

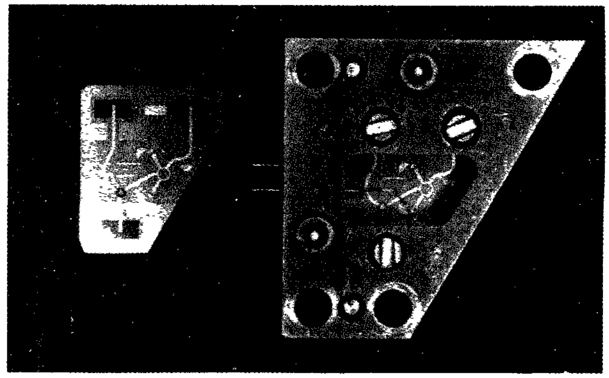

FIG.7. VIEW OF MIXER SUBSTRATE AND ASSEMBLED MIXER

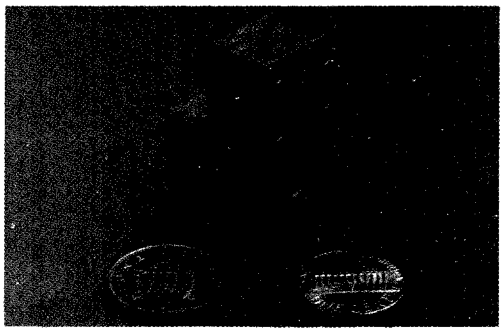

FIG.8. OSCILLATOR AND ISOLATOR.

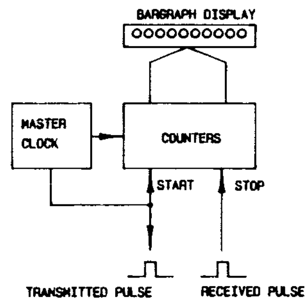

FIG 9. RANGING CIRCUIT

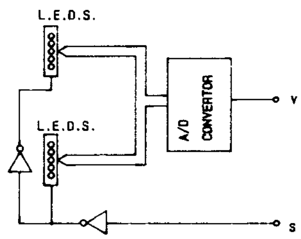

FIG.10. ELEVATION DISPLAY

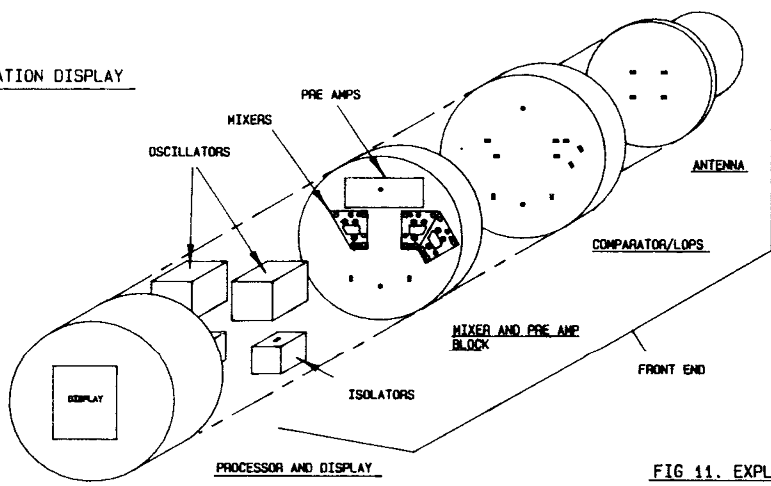

FIG 11. EXPLODED VIEW OF RADAR ASSEMBLY