Direction-Finding Performance of a *Ka*-Band ESM Receiver

Erik Boch, *Member, IEEE*, and Michael Stapleton

***Abstract*—Although development of Electronic Warfare (EW) receivers has begun to address the need to detect millimeter wave radars, very little ESM performance data have been provided to the system engineering community. This has partially been a result of the sensitivity of some millimeter wave applications.**

This paper provides a sample of direction-finding (DF) measurements derived from tests carried out on an advanced development model (ADM) millimeter wave (28–40 GHz) ESM receiver using an outdoor test range. DF accuracies of 5–6° rms are demonstrated as being readily attainable *Ka*-band using conventional amplitude comparison monopulse techniques [1–3] combined with high probability-of-intercept and large instantaneous dynamic range.

I. Direction-Finding Receiver Description

THE architecture of the wideband receiver employed in these tests is shown in Fig. 1. Monopulse bearing is measured through the use of a circular eight-port direction-finding array. On each pulse intercepted, the receiver produces a digital pulse descriptor word (PDW) output containing pulse width (PW), bearing, amplitude, time-of-arrival (TOA), and frequency band. A number of quality indication flags are also produced to determine the usefulness of the measured data.

Table I shows a list of error factors (and budgeted error allowances) within a typical millimeter wave amplitude comparison monopulse DF receiver. Table I also shows the techniques used to compensate for each error in order to improve direction-finding performance. The factors which are not easily compensated for include elevation, polarization, alignment and quantization. The peak residual error due to these factors and nonideal compensation is ~6 – 8 dB and a resulting predicted DF accuracy of ~4 – 5° rms [3].

In these preliminary tests, a simple bearing correction scheme is employed which relies on monopulse and receiver characterizations carried out in isolation. This does not fully compensate for the monopulse characteristic of the DF array and thus will provide slightly degraded DF accuracy performance.

II. Direction-Finding Test Results

A series of tests were conducted on a test range to determine the direction-finding performance attributes of the receiver for both vertical and horizontal linear polarizations. Fig. 2 shows measured DF accuracy versus angle of arrival in a typical 45°

Manuscript received August 24, 1993. This work was supported by the Defence Research Establishment (DREO), Ottawa, Ont., Canada.

The authors are with Lockheed Canada Inc., Stittsville, Ont., Canada K2S IE6.

IEEE Log Number 9214846.

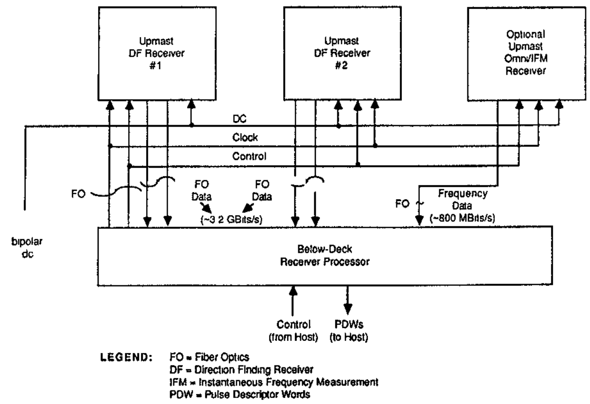

Fig. 1. Top-level block diagram of the millimeter wave receiver.

TABLE I
Error Factors and Real Time Compensation Techniques

	Factor	Approximate Peak Error Budgeted	Compensation Technique
i)	Noise effects	2 dB	- design receiver to operate with SNR of 15 dB (min)
ii)	Elevation effect	2 dB	- measure instantaneous elevation and use for correction
iii)	Polarization effects	3 dB	- measure instantaneous polarization and use for correction
iv)	Frequency effects on antennas	2 dB	- full array calibration and pulse-to-pulse correction
v)	Frequency effects on receivers (flatness)	2 dB	- full calibration of receiver channels and pulse-to-pulse correction
vi)	Powee-induced errors on receivers (linearity)	1 dB	- full calibration of receiver channels and pulse-to-pulse correction
vii)	Alignment and calibration errors	1 dB	- not readily avoided
viii)	Receiver temp. drifts	1 dB	- track offset drifts, compensate (digitally)
ix)	Quantization errors	.25 dB	- decrease resolution cell size (technology limited)

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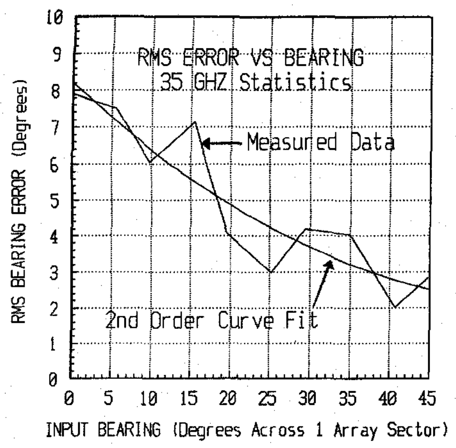

Fig. 2. Measured direction-finding accuracy @ 35 GHz.

bearing sector at 35 GHz (midband). At this test frequency, the rms accuracy of the receiver is 5.2 degrees.

Although the measured DF accuracies are compatible with expected performance, the variation in the accuracy plot of Fig. 2 is somewhat atypical of an amplitude comparison monopulse DF system. Typically, at low/moderate signal-to-noise ratios (SNR), the array DF accuracy is worse on the antenna element boresights (shown as 0° and 45° on Fig. 2) and improves toward the centre line of the elements (shown as 22.5° on Fig. 2). The atypical characteristic of the measured data may be explained through the statistical nature of the sample set and the simplistic calibration scheme employed in this preliminary testing. Factors not accounted for in the calibration include antenna-housing effects and antenna-receiver impedance matching. Both of these factors will cause unpredictable distortion of the array monopulse characteristics.

III. Conclusions

The results of the initial direction-finding tests carried out on the wideband millimeter wave ESM receiver have resulted in monopulse direction-finding accuracies of 5 degrees rms. These results are in relatively close agreement with estimated performance expectations. Further testing of the subsystem will be carried out using improved bearing correction/compensation techniques in order to achieve improved performance and to further understand all sources of error in bearing estimation.

Acknowledgment

The authors acknowledge the technical support (in particular that of Robert Inkol) of the Defence Research Establishment (DREO) in Ottawa, Ont., Canada.

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