AN OCTAVE BANDWIDTH MONOPULSE PROCESSOR

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Abstract— **An octave bandwidth monopulse processor has been designed to operate from 2 to 4 GHz. The design is based on a new architecture in which two 90° delay lines and a 0 dB coupler are used in the monopulse circuit. The 2-4 GHz bandwidth is obtained in the difference port in which the dispersion due to the two 90° delay lines cancels. The simulated results demonstrate a 20 dB null depth over a 2 GHz bandwidth and a sum variation of 1 dB when using Lange couplers for the 0°/90° hybrids. The monopulse processor was fabricated on a 510 μm high resistivity silicon substrate. The measured results indicate an 18 dB null over a 2 GHz bandwidth and a 30 dB null over a 0.95 GHz bandwidth centered at 2.6 GHz with a 2 dB variation in the sum pattern. This novel monopulse circuit can be used in millimeter-wave wideband radars (8-16 GHz, 20-40 GHz) or in novel IF-based monopulse systems.**

I. Introduction

The monopulse processor is a critical component of monopulse radar systems. It forms the sum and difference channels (azimuth and elevation) from four antenna inputs as shown in figure 1(a). The sum, azimuth difference, and elevation difference signals are used to determine the angular position of the target relative to boresight. The monopulse configuration is the standard technique used for high accuracy tracking with typical applications including airport traffic control, aircraft defense, and ship defense.

Waveguide monopulse processors have typically been designed using 0°/180° 3 dB couplers (waveguide magic-tees). However, 0°/180° 3 dB couplers cannot be used in planar circuits due to the positioning of the sum and difference ports. As a result, 0°/90° 3 dB couplers are used with 90° delay lines to synthesize the monopulse pattern as shown in figure 1(b) [1]. Unfortunately, the additional 90° delay lines create extra dispersion in the monopulse processor which limits the 30 dB null bandwidth to ±4%.

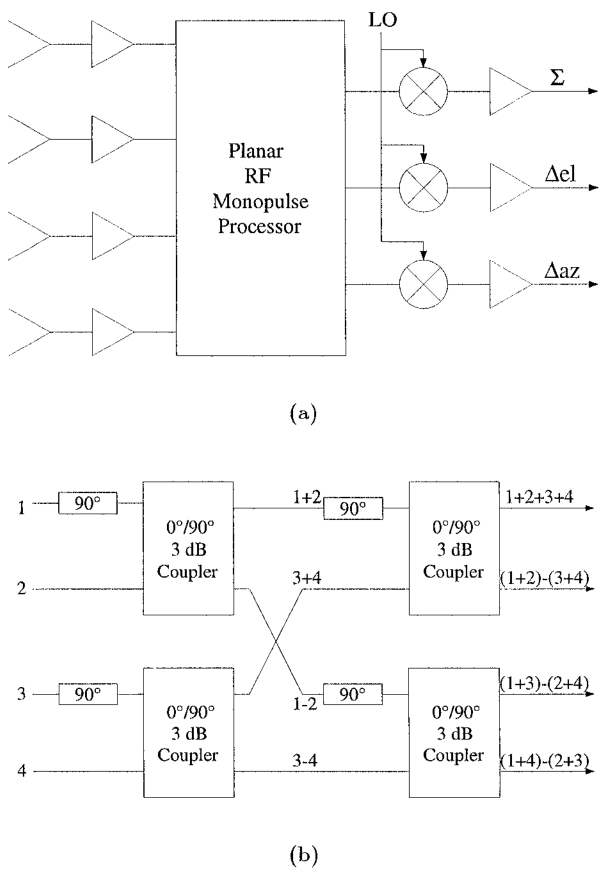

Fig. 1. (a) Monopulse radar receiver with (b) a standard monopulse processor using 0°/90° 3 dB couplers.

In order to increase the bandwidth, we have designed a new architecture for the planar monopulse processor in which a 0 dB coupler is used as shown in figure 2(a) [3]. The 0 dB coupler is formed by cascading two 0°/90° couplers and allows the two signals, -(1-2) and -j(3+4), in the middle of the monopulse processor to cross over one another without coupling. The 0 dB coupler also delays each of the signals by 90° which eliminates the need for the two 90° lines in the standard monopulse configuration. The two delay lines at the input to the monopulse processor still cause dispersive effects in two of the difference ports; however, in the third difference port ($\Delta 3$ in figure 2), the dispersive effects cancel out and result in a very wideband null. Therefore, two of these processors could be used to generate the wideband difference signals (azimuth and elevation) needed for tracking applications.

The wideband monopulse processor is also an excellent choice for the new IF-based monopulse processors first proposed by Ling *et al.* [2]. In this configuration, the RF channels are amplified, mixed down to an IF, amplified again and then sent to the monopulse processor. The IF-based monopulse processor reduces the complexity of the RF front-end and enables the use of additional amplification at the IF to reduce the effects of loss in the processor. The novel monopulse processor allows a wideband millimeter-wave signal to be processed at low IF frequencies (2-4 GHz).

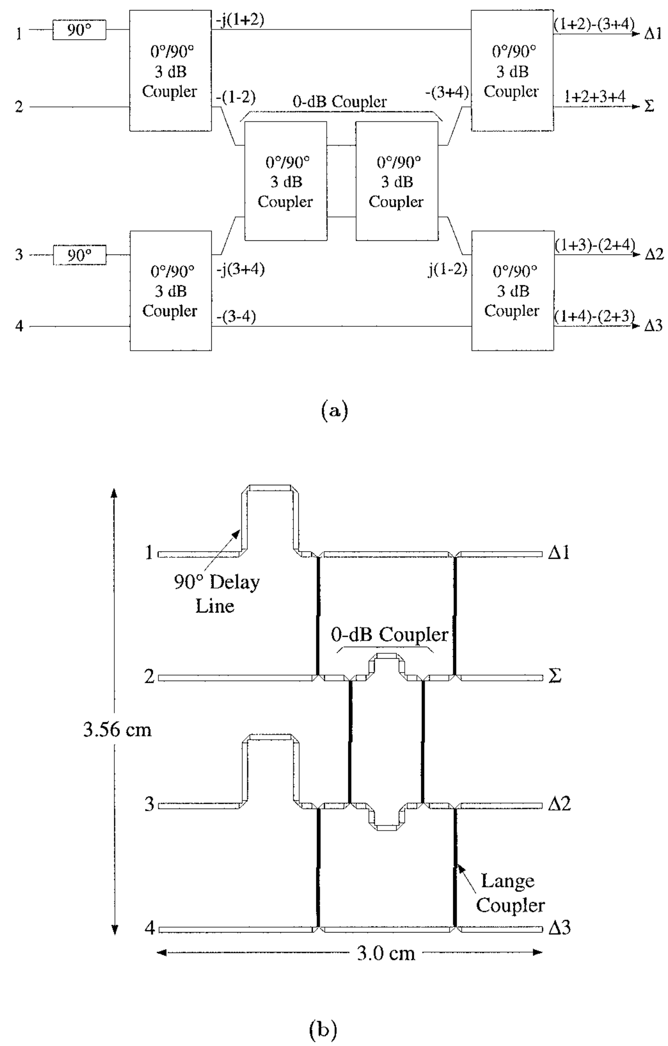

Fig. 2. Monopulse processor using a 0 dB coupler; (a) concept and (b) layout using Lange couplers.

II. Design and Measurements

In order to achieve the largest possible bandwidth, the monopulse processor was designed using Lange couplers for the 0°/90° 3 dB couplers. As can be seen from figure 2(b), this results in an elegant and compact design. The processor was designed for a 525 μm high resistivity silicon substrate and simulated using HP EEsof's Libra [4]. The simulated results shown in figure 3(a) demonstrate a difference port with a 20 dB null-depth over a 2 GHz bandwidth centered at 3 GHz and a sum pattern with a 1 dB variation over the bandwidth. The remaining two difference ports are of standard bandwidth due to the dispersion effects of the input 90° delay lines.

The width of the lines in the Lange coupler is 29 μm and the seperation between the lines is 39 μm. The couplers are 9.46 mm long and the 50 Ω lines are all 0.43 mm wide. The microstrip transmission lines are gold plated to a thickness of 3 μm and the ground plane is gold plated to a thickness of 6 μm. The input and output lines are all spaced 1 cm apart which allows SMA connectors to be used without the need for additional spacing. An aluminum mount is used to hold the silicon wafer and connectors, and the connections between the SMA connectors and the microstrip lines

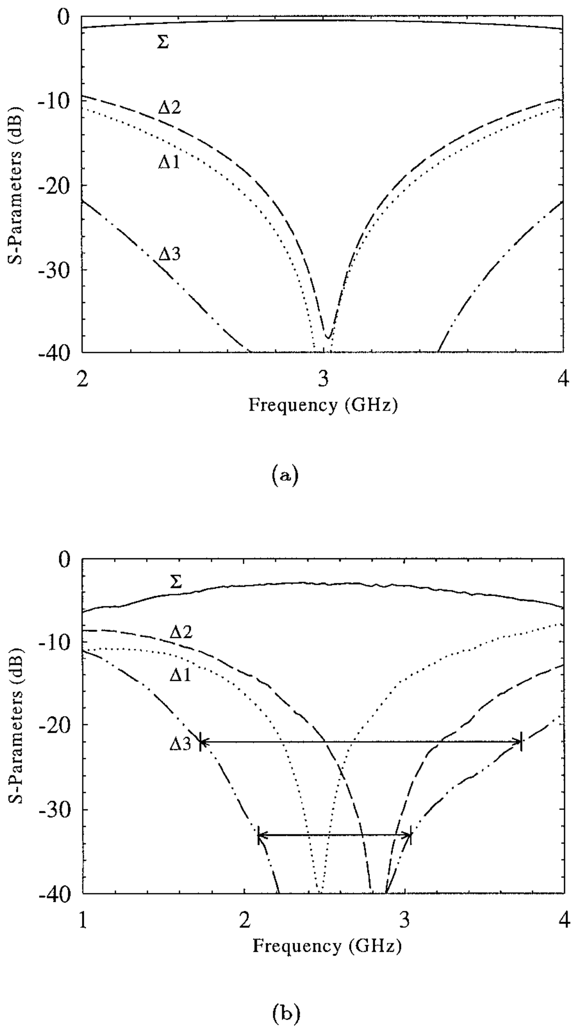

Fig. 3. (a) Simulated and (b) measured response for the Lange coupler based monopulse processor.

are made with silver epoxy.

The monopulse processor was tested using a Mini-Circuits 2-4 GHz 4-way power divider and an HP 8720 vector network analyzer. As can be seen from figure 3(b), the center frequency of the monopulse processor is shifted down in frequency to 2.6 GHz. However, even with this shift in frequency, a wideband difference port is obtained with an 18 dB null over 2 GHz and a 30 dB null over 0.95 GHz. The shift in the measured frequency response is due to phase error in the Lange couplers. The increased loss in the measured data is due to the connectors and skin effect losses since the transmission lines are only 1.2-2.4 skin depths thick from 1-4 GHz.

III. Conclusion

We have demonstrated a wideband Lange coupler based monopulse processor centered at 2.6 GHz with an 18 dB null over 2 GHz. This design can be scaled up to X-band or K-band in order to obtain much greater bandwidths (8-16 GHz, 20-40 GHz) if necessary. The monopulse processor has also proved to be very useful in the new IF-based monopulse systems, allowing the processing of 2 GHz wideband signals from a 94 GHz radar system.

IV. Acknowledgment

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References

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