A SINGLE CHANNEL MONOPULSE ANTENNA WITH LOW EFFECTIVE SIDELOBES

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ABSTRACT

This paper describes a CSC^2 single axis tracking antenna using a single channel monopulse antenna which has improved sidelobe performance over conventional single channel monopulse antennas. Effective sidelobes of the composite pattern, measured at the receiver input, greater than 22 dB have been achieved. This is due to a unique feed design. The composite patterns are the true measure of performance for a single channel monopulse system since this is the input to the tracking receiver. The low effective sidelobes result in a significant reduction of multi-path problems.

INTRODUCTION

The use of single channel monopulse antennas in automatic tracking systems has been very popular since its inception in the early 1960's. The major advantages are no moving parts resulting in a high degree of reliability and a high scan rate. The major drawback has been degraded low angle tracking caused by high effective sidelobes of the composite patterns.

A single channel monopulse antenna can be designed with low sidelobes for both the sum and difference channels. However, in a single channel monopulse system these sidelobes are not the determining factor in the performance of the system. The antenna's sum and difference channels are input to a scan converter. The scan converter vectorially combines the sum and difference patterns into a composite pattern. The output of the scan converter is the input to the tracking receiver. The effective sidelobes of the composite patterns determine the overall performance capability of the single channel monopulse antenna.

A scan converter is a device which receives the sum and difference channel inputs from the antenna, phase reversal modulates the difference channel, and vectorially combines it with the sum channel to a single RF output. A block diagram is shown in figure 1. The difference channel signal is input into a phase reversal modulator and then recombined with the sum channel in the directional coupler. The phase reversal modulator modulates the difference channel signal 0º - 180º at the scan rate. The scan converter output is a modulated RF signal as shown in figure 1.

The 0º and 180º modulation of the difference channel produces the mechanical equivalent of suppressed carrier amplitude modulation (AM). The addition of the sum signal in the directional coupler is the reinsertion of the carrier to produce a double sideband AM signal or the mathematical equivalent to conical scanning in a single plane. Thus, the name scan converter. The output of the scan converter is the composite crossover pattern. The composite crossover pattern (0º and 180º position of the switch) is equivalent to the radiation pattern of a mechanical scanner with the scanner in the two opposite positions.

It is the effective sidelobes of the composite patterns that causes the severe multi-path problems. The lowest effective sidelobes obtainable with conventional single channel monopulse systems is 15 dB. Phase and amplitude errors can cause further sidelobe degradation. The reason for this limit is that the difference pattern peaks occur almost at the same angle as the sum pattern first null. When the sum and difference patterns are vectorially combined in the scan converter the difference pattern peak becomes the first sidelobe of the composite pattern. This sidelobe is typically 15 dB down from the peak of the crossover pattern[1].

LOW EFFECTIVE SIDELOBES

In order to achieve multi-path enhancement the composite patterns must have low effective sidelobes. The single channel monopulse antenna system described herein achieves effective sidelobe levels greater than 22 dB. The low sidelobe levels are a result of a unique feed design. The antenna system configuration is shown in figure 2. Figure 3 shows the sum and difference radiation patterns at 4.4 GHz of the single channel monopulse antenna. The sidelobes of the sum channel are 23 dB down from the peak.

As shown in figure 3, the difference pattern peaks are no longer aligned with the sum pattern first nulls. In fact, the difference channel nulls are very close to being superimposed with the sum channel nulls. Figure 4 shows the difference channel peaks attenuated 15 dB from the sum channel peak. This is the relative amplitude level accounting for the directivity of the directional coupler. Figure 4 is the sum and difference patterns prior to vectorial addition.

The vectorial addition of the sum and difference patterns, for the 0º and 180º phasing, results in the composite crossover patterns shown in figure 5. The sidelobes are greater than 22 dB down from the peak. The sidelobes of the crossover patterns are only 1 dB worse than the original sum pattern sidelobes. Thus, when the sum and difference channel first nulls are almost superimposed the sidelobe of the composite crossover pattern is only slightly higher than the sum pattern sidelobe. This antenna performance is a significant improvement over previous single channel monopulse systems with less than 15 dB sidelobe levels.

Previously, when low sidelobes were required a single channel monopulse antenna was not considered as a viable alternative due to its high effective sidelobes. Typically, a conical scanner antenna was preferred in these situations[2]. This single channel monopulse antenna, however, has equivalent sidelobe performance to the conical scanner antenna.

ANTENNA DESIGN

The antenna portion of the monopulse system consists of a six foot cosecant squared reflector, dual waveguide diffraction plate feed, and a broadband waveguide magic tee. The reflector is a lightweight, yet durable fiberglass design. It is a doubly curved reflector to produce a CSC^2 radiation pattern in the elevation plane and a pencil beam radiation pattern in the azimuth plane.

The feed unit consists of a dual waveguide diffraction plate feed and a magic tee. The diffraction plate is mounted at the end of the dual WR159 waveguide. The diffraction plate is designed to provide optimum illumination in order to achieve maximum gain with low sidelobes. The combination of the diffraction plate and the spacing between the dual waveguide centers are key to the excellent performance of the antenna. The dual waveguide is flange mounted onto a magic tee in order to obtain the sum and difference channels. The magic tee has a circular mounting flange which fastens to the center of the reflector surface. A hole in the center of the reflector is large enough to allow the magic tee to pass through when the feed is inserted from the front of the reflector. This mounting configuration allows for minimal feed blockage and has sufficient rigidity that additional supports are not necessary. These factors all contribute to the overall performance of the system.

The magic tee is a TSA custom designed waveguide H-plane folded tee. A waveguide magic tee was selected due to its relative ease in manufacturing once the design is complete. It is also a very pure 180º hybrid over a broad frequency range. The magic tee was designed as an H-plane folded tee due to its small size and excellent packaging arrangement with the dual waveguide diffraction plate feed. The magic tee by itself has an operational bandwidth of 4.4 to 5.8 GHz with a VSWR $\leq$ 1.15:1. This is a bandwidth of more than 30%. Standard off the shelf units from microwave component manufacturers have typical bandwidths of 15% or less.

The H-plane folded tee has an output power unbalance less than 0.2 dB from 4.4 to 5.8 GHz. The isolation between the sum and difference ports is greater than 30 dB. In-line waveguide to coaxial transitions are built into the sum and difference ports of the magic tee. The in-line transition from waveguide to coaxial line allows for convenient cable connections to the scan converter.

The complete antenna with feed weighs less than 80 lbs. The polarization is configured for linear vertical. The H-plane beamwidth is a nominal 2.7º at 4.4 GHz. The E-plane beamwidth is CSC^2 to approximately 45º. The boresight shift versus frequency was measured to be less than 0.08º from 4.4 to 5.1 GHz. The linearity of the error signal is shown in figure 6. The error signal is the difference between the composite crossover patterns for 0º and 180º phasing. The figure also shows a tracking capture angle capability of ±20º from boresight.

CONCLUSION

A single channel monopulse antenna has been presented that has low effective sidelobes. The low sidelobes are attributable to a unique feed design which results in the sum and difference patterns having their first nulls almost superimposed. When this occurs, the sidelobes of the composite crossover pattern are almost as good as the actual sum pattern sidelobes. The low sidelobes of the crossover pattern significantly reduces multi-path problems. This single channel monopulse antenna has a simplistic design, optimum performance characteristics, and extremely high reliability. The system design is applicable to several other frequency bands, particularly L, S, C, X, and Ku-band devices.

REFERENCES

1. Arthur Sullivan, "Selection of Optimum Antennas for Tracking Telemetry Instrumented Airborne Vehicles," International Telemetering Conference, October 1980.

2. Arthur Sullivan, "RADSCAN, A Novel Conically Scanning Tracking Feed," International Telemetering Conference, September 1982.

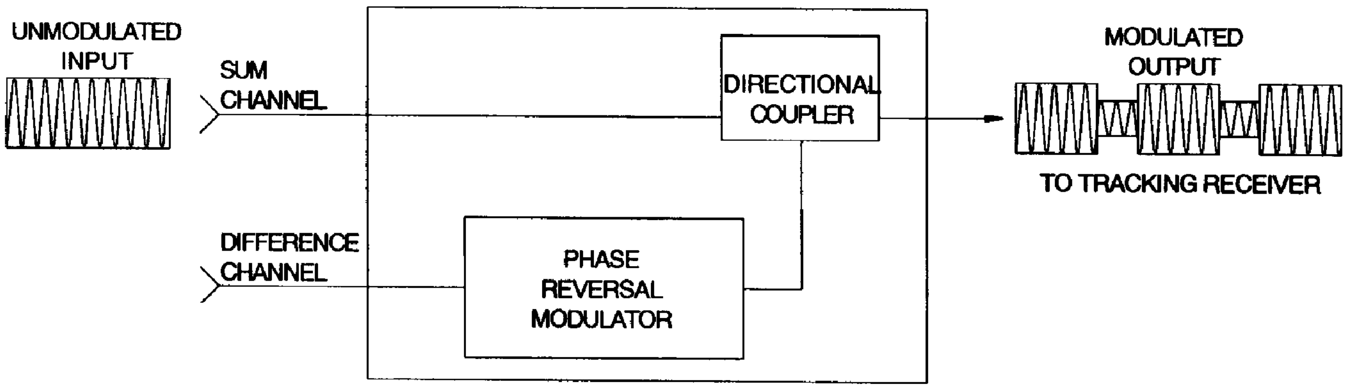

Figure 1 - Scan converter block diagram

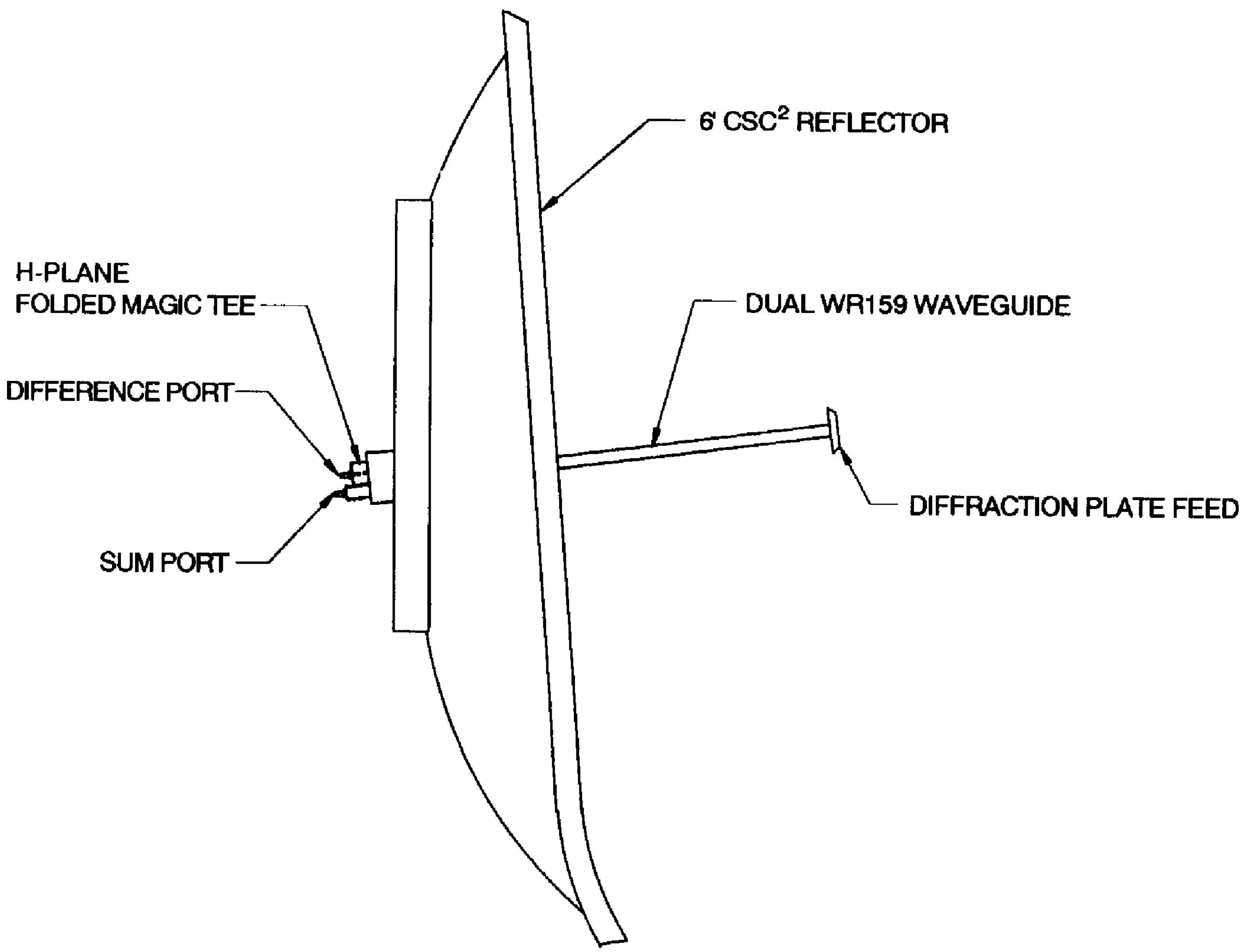

Figure 2 - Single channel monopulse antenna

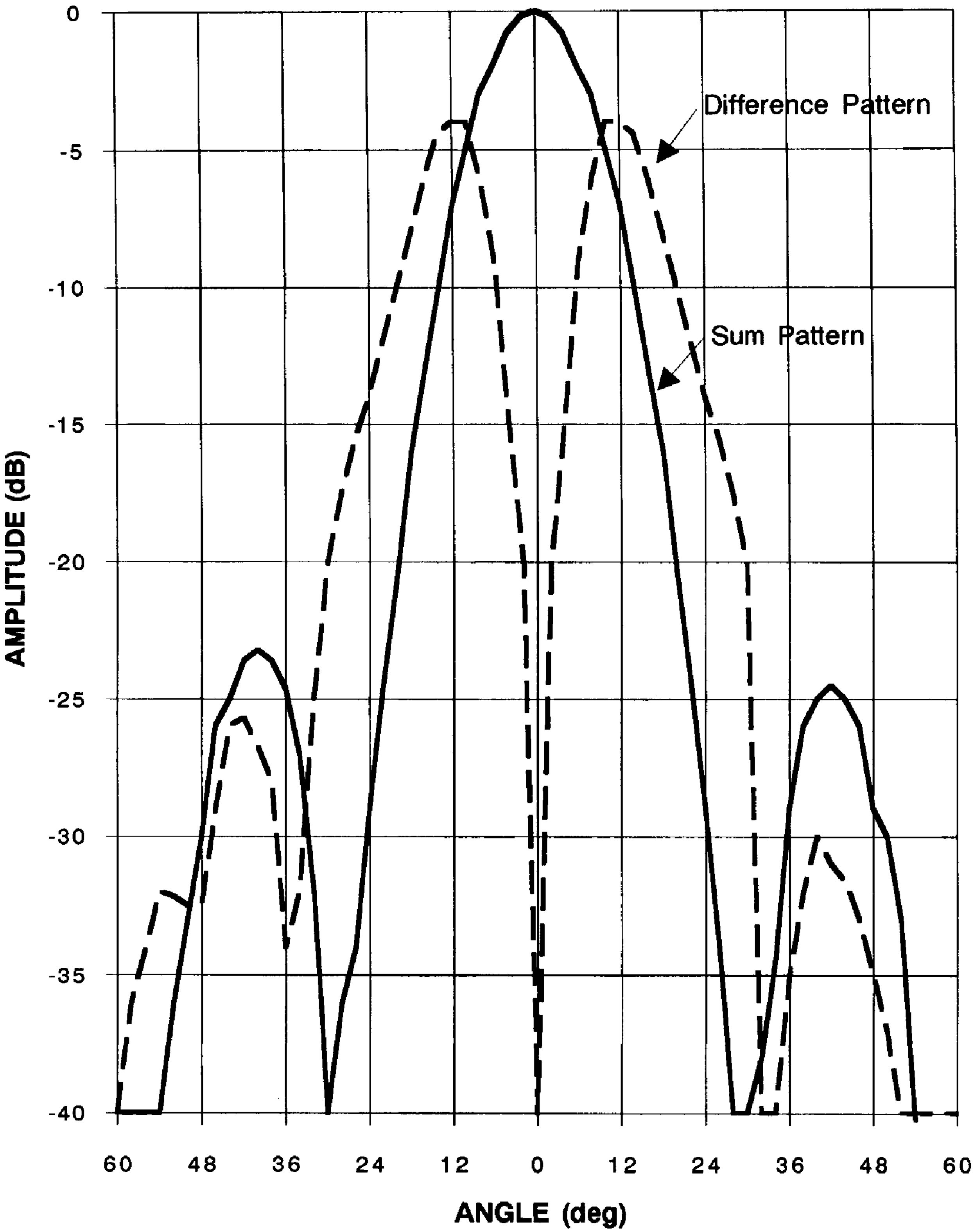

Figure 3 - Sum and Difference Patterns

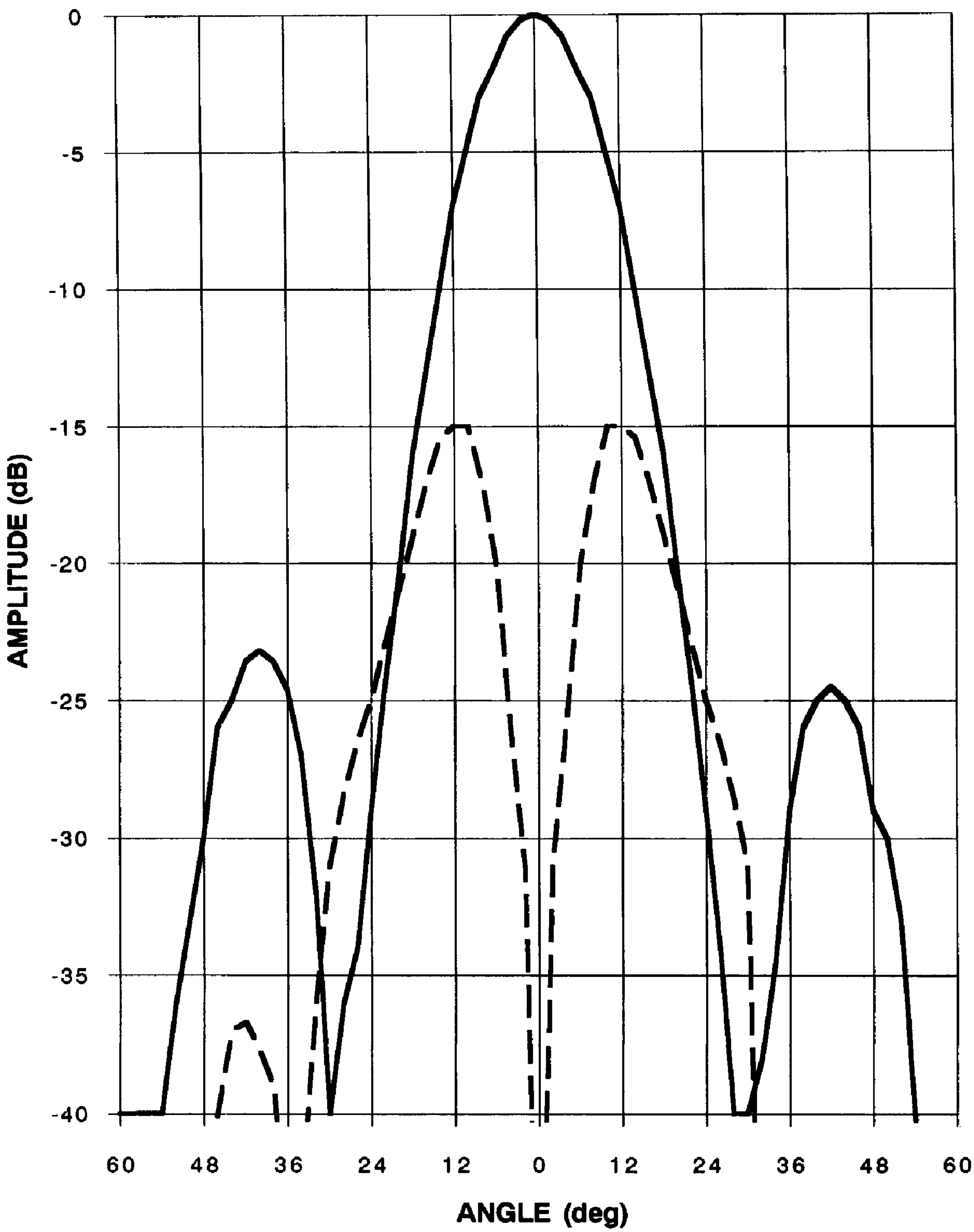

Figure 4 - Sum and Difference patterns
before vectorial addition

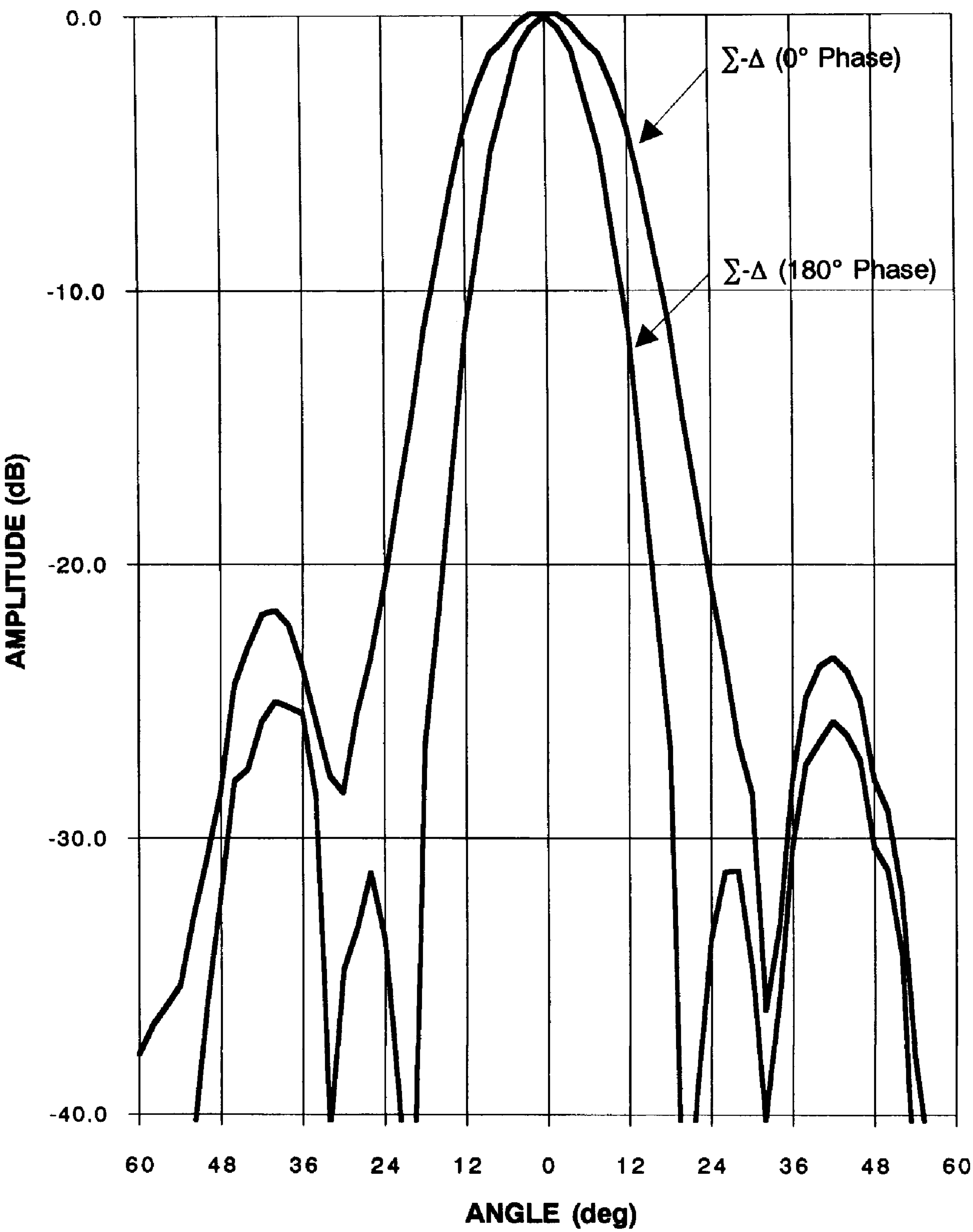

Figure 5 - Composite crossover pattern

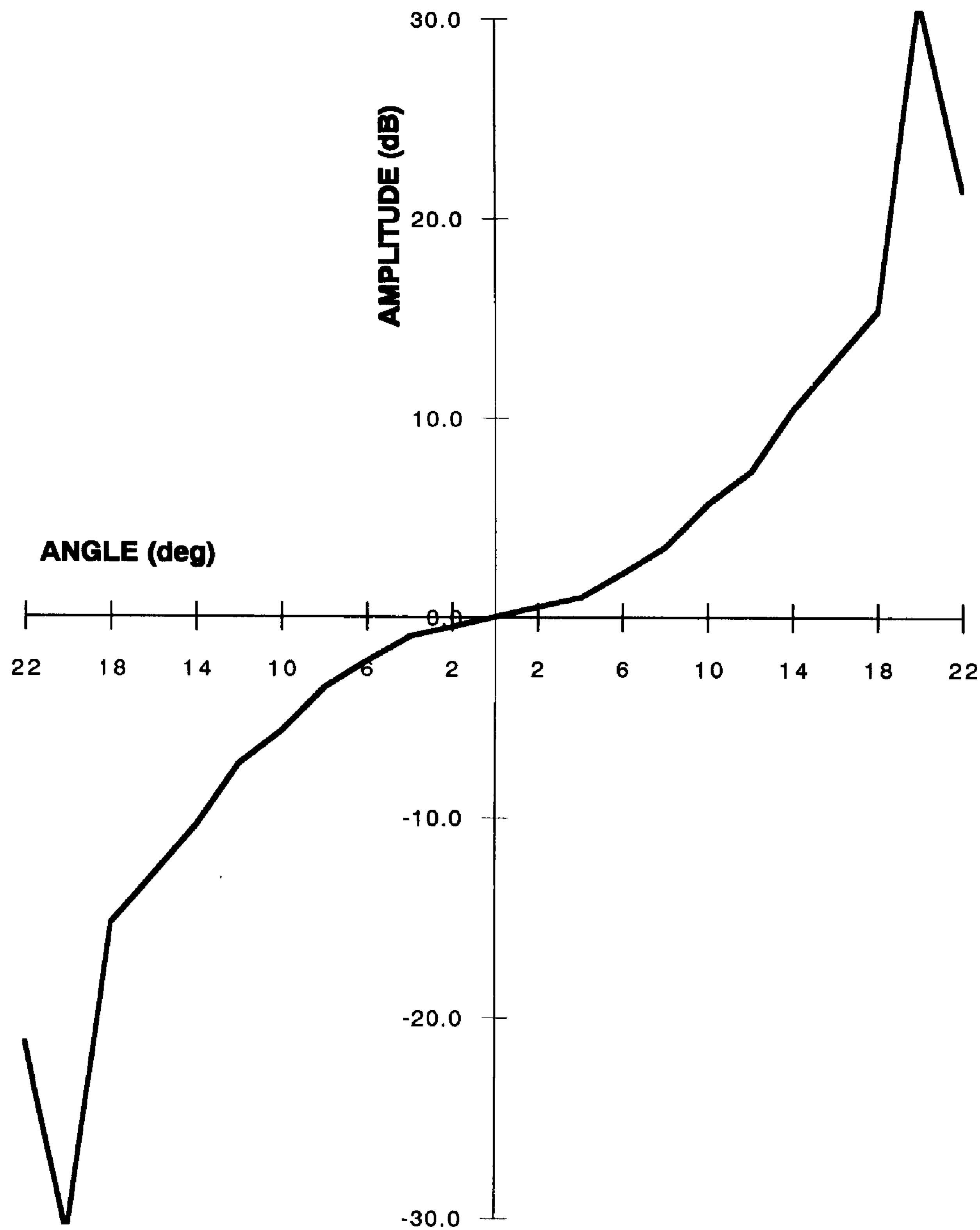

Figure 6 - Error signal