MICROWAVE DESIGN OPTIMIZATION OF THE TSC AUTOMOBILE CRASH SENSOR*

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Abstract

This paper reports recent progress in optimizing microwave design of TSC's automobile crash sensor. This system is a bistatic cw radar employing homodyne detection and digital processing of the doppler signal, to detect impending crashes.

Introduction

This paper reports recent progress in optimizing the microwave portion of the automobile crash sensor system that has been developed at the Transportation Systems Center.[1,2,3] This sensor system is for use in triggering passive restraints for protecting automobile passengers in high-speed crashes. In high-speed crashes, the finite deployment time of restraints such as "air bags" proves a problem. There is a practical limit to how fast deployment can occur without the restraint injuring the passenger, and how slowly deployment can occur and still yield effective passenger protection. One answer to this problem is to reach out in front of the auto 1 to 2 meters with a radar, and actuate the restraint system tens of milliseconds prior to impact, thus allowing adequate protection with moderate deployment speeds.

Current microwave technology is fully capable of performing this task technically, but that is only part of the problem. To be wholly effective, a microwave system for this function must withstand the rigors of the automotive environment, the typical patterns of maintenance given private autos, and the severe cost constraints present in the automotive market. These factors were kept in view from the outset, with the hope that they could be dealt with adequately.

The Initial System

The first crash sensor system designed was a 10.5 GHz cw radar powered by a Gunn diode, with a transmitting horn mounted in the grille at one front corner of the automobile, and a receiving antenna at the other. Both antennas had 26° beamwidth. The axes of their beams intersected 2 meters in front of the grille. The region of maximum sensitivity to intruding objects, where an object caused a return within 3 db of maximum, was a spheroidally shaped region approximately 30 cm in diameter, centered 1 meter in front of the grille. In this system, the received signal was mixed with a sample of the transmitted signal to produce a doppler beat signal. The doppler signal from a crystal mixer was amplified and tested for frequency and amplitude to determine whether a dangerous crash was immanent. This system worked when installed in a test automobile but was far from optimum.

Multi-Channel System

In order to obtain a region of maximum sensitivity that extends entirely across the front of the auto, computer analysis was conducted of multi-channel systems using more than two antennas. On the basis of the computer analysis, a two-channel system was chosen. In this arrangement, each channel uses one wide-beam and one narrow-beam horn for transmitter and receiver respectively. Each pair is so aimed as to cover half of the front of the auto, yielding a strip of essentially constant sensitivity entirely across the front of the auto, approximately 1 meter away.

The two channels must be essentially non-interacting. This can be accomplished by using different polarizations for each channel, or different microwave frequencies. There are advantages and disadvantages to either option, relating to the cost of microwave sources, the possibility of using the additional information available in a two-channel system to improve the false-alarm vs. miss tradeoff, the problems of potential intervehicle interference between similarly equipped autos, and questions of system complexity and overall reliability.

One possible advantage of a two-frequency system in eliminating intervehicle interference can be seen from the following analysis: If systems such as this cime into general use, they will probably be assigned a band of frequencies in X-band or slightly above on the order of 100 MHz wide. Assuming a 3-kHz channel width, corresponding to twice the doppler frequency generated at relative velocities of 200 mph in an X-band system, there are essentially 33,000 independent channels. This means that on the average of once in every 33,000 sufficiently close passes by other vehicles another vehicle's transmitted signal would enter your system, appear like a doppler-shifted return, and erroneously actuate it. This could happen once a day in heavy traffic. But now consider a two-channel system in which <u>some</u> signal must be received by each channel in order to actuate. With two independent channels in each vehicle, there would be $(33{,}000)^2$, or 10^9 possible combinations--more than the world's entire automobile population. Even with randomly chosen combinations, one false actuation in 10^9 near passes is considered an acceptable level.

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Other Factors

The choice of optimum frequency is also being investigated. Channels for new applications are more readily available above X-band, but microwave sources and other hardware items are more expensive at the higher frequencies. Radar signiatures of various potential targets--trees, automobiles, concrete walls, etc., are being measured at 22 and 35 GHz in order to compare results with those already obtained at 10.5 GHz. The question of optimum microwave power level is being studied as well, from the viewpoint of radio interference, system sensitivity, cost, and health. Antenna construction is being investigated, with special consideration of planar array antennas, since these have much less total bulk than do horns of equal gain--a fact that would simplify installation--and they may cost less in volume production as well. Other related areas of current work include a hybrid crash sensing system that combines radar and mechanical sensing, and the use of simple digital logic circuitry for simultaneously processing the radar-derived and mechannically derived signals; it is anticipated that such a hybrid system will offer greater freedom from false alarms and misses than either a radar system or mechanical system alone.

Conclusion

In summary, the TSC microwave automobile crash sensor is a still evolving system employing state-of-the-art microwave and electronic techniques in an application in which the potential market is very large, but in which the design constraints are many and severe. The crash sensor does detect impending crashes; the inescapable question that also must be answered is how reliably for how long at what price.

References

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