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Modeling the Feed System of a Monopulse Tracking Radar using the FDTD Method

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Abstract

The design of a reflector antenna feed for the monopulse tracking radar application is presented. The feed consists of a rectangular-circular mode coupler to isolate the sum and difference channels required for the monopulse tracking, and a corrugated horn for symmetric radiation pattern with low cross polarization. The modeling is carried out by using the Finite Difference Time Domain (FDTD) Method, which is well suited for field visualization. The measurements show that the feed performance meets the design requirement and is in close agreement with the FDTD prediction.

Introduction

Although there exist many different types of tracking radar systems, all of them are based on sensing the pointing angle error, which is defined as the angle between the boresight and target lines. What distinguishes different tracking radars is the way they detect this error. Once the error is detected the antenna simply points in that direction and therefore constantly keeps track of the moving target by minimizing the error. The conical scan is a classic example of tracking radar in which the angle error is detected by rotating the antenna beam around the boresight while receiving the echo signals. Comparing these signals that arrive with different amplitudes enables the system to detect the angle error. The drawback of conical scan is in the pulse-to-pulse fluctuations and its limitations due to the pulse intervals. The monopulse tracking radar, on the other hand, uses a single pulse and, hence, is not prone to the error caused by the random changes in the radar cross section of the target. However the monopulse feed for a reflector system contains more complexity.

In order to support simultaneous performance of the two channels, viz., data (sum channel) and tracking (difference channel), the sum pattern must be designed to have a maximum in the boresight for maximum reception of the data, whereas the difference pattern requires a sharp null in the boresight for a sensitive tracking of the target. In this paper, we present the design of a monopulse feed, which uses TE11 (sum pattern) and TE21 (difference pattern) modes in a circular waveguide flared out into a corrugated horn. The rectangular-circular mode coupler is used to separate the channels. The Finite Difference Time Domain (FDTD) Method [1] is used in this work as the main design tool, since the visualization capability of this method allows us to have a good physical insight in the entire design process.

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Monopulse feed design

Figure 1 shows the schematic of the design for the monopulse feed. It consists of a corrugated horn and a rectangular-circular mode coupler. The corrugated horn is designed to have 10 dB taper in 20 degree for all the planes. The axial symmetry is exploited in this part and Body of Revolution version of the FDTD Method [2-3] is used to model the horn and obtain both far-field pattern and reflection coefficient. The depth of the corrugations is chosen to give the symmetric pattern [4] in all the planes as well as suppressing the unwanted peaks in the reflection coefficient in the vicinity of the operating frequency. The horn is connected to a circular guide in which the coupling to the rectangular guides takes place.

The mode coupler, shown in Fig.2, consists of a circular guide surrounded by 8 rectangular guides. Each waveguide has a low power load at one end, and a waveguide to coax connector at the other. There are 16 holes that are quarter wavelength apart in the sidewall of each waveguide that goes through into the circular guide. The scheme allows the flow of TE21 mode in the circular guide to be coupled into the TE10 mode in the rectangular guide. Both right and left hand circular polarizations are detected using all the eight guides. The circular guide is tapered down into the smaller diameter for which only the TE11 mode propagates, and the OMT for the data channel receives both the horizontal and vertical polarizations. We model the coupler (Fig.3) by using the FDTD for only one pair of these rectangular guides. The size of the holes is optimized, based on several FDTD runs, to achieve proper coupling.

Numerical and measurement results

The simulation results obtained by using the Body of Revolution FDTD code for the corrugated horn are shown in Figs. 4-5. The symmetric pattern with 10 dB taper in 20 degree is achieved for the E-, H- and 45-deg planes.

The phase distribution inside the mode coupler is shown for both TE11 and TE21 in Fig.6. The coupling through the holes in the rectangular guides is evident from the figure. It is also evident that two modes generate different radiation patterns. In the TE21 mode (right) the opposite phase lead to the field cancellation in the boresight and hence a sharp null.

The measurement results for both sum and difference patterns of the monopulse feed are shown in Fig. 7. The 40 dB difference in the sum and difference channels in the boresight assures the high sensitivity of the target tracking.

References

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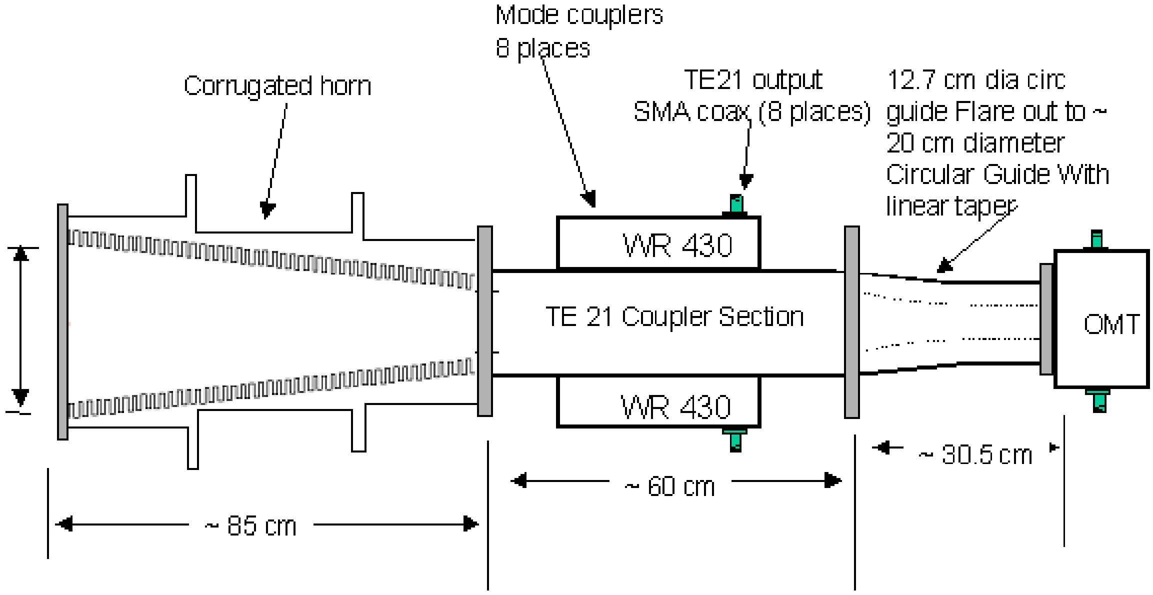

Fig.1 Monopulse feed with a circular-rectangular mode coupler.

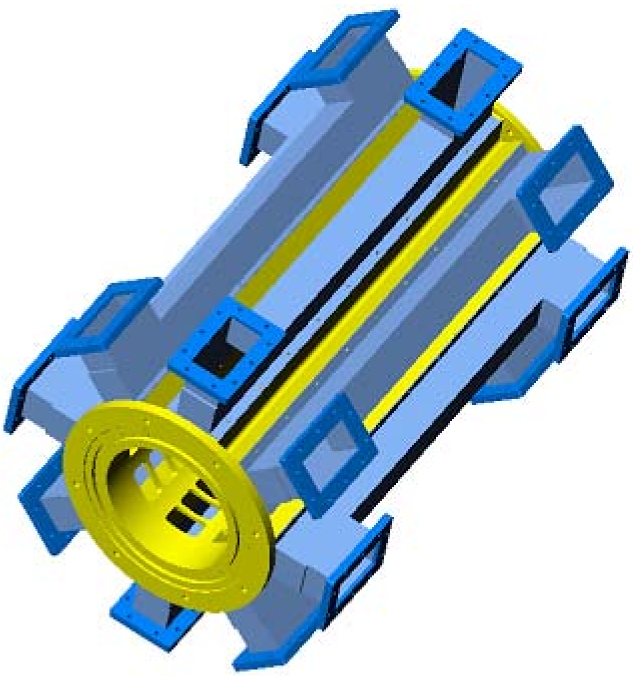

Fig.2 Circular to rectangular mode coupler.

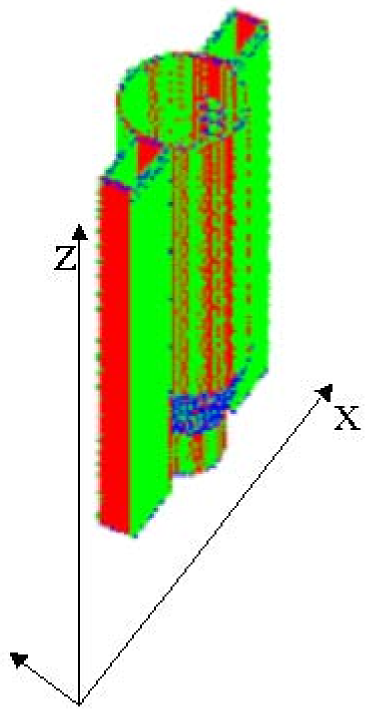

Fig.3 Coupler modeling in the FDTD Method. Only one pair of rectangular guides is modeled.

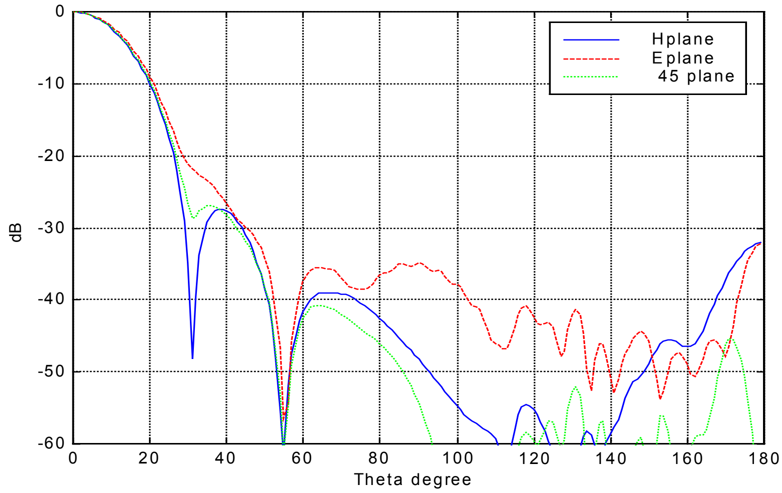

Fig.4 Far field pattern of the corrugated horn at 2.25 GHz in different planes, computed by using BOR-FDTD.

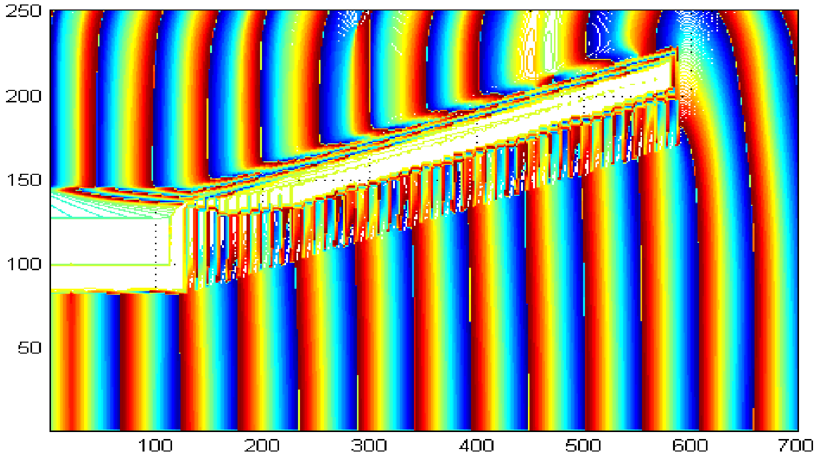

Fig.5 Phase distribution in the cross section of the corrugated horn at 2.20 GHz.

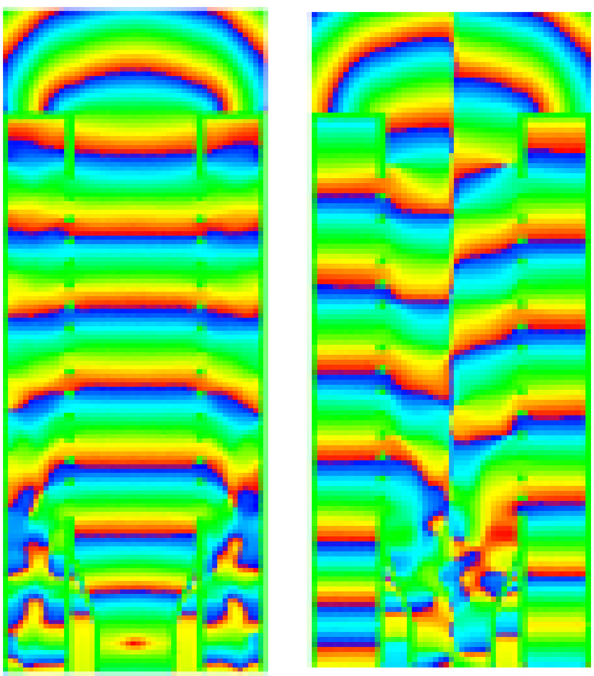

Fig.6 (left)Phase distribution in the cross section of the mode couple for sum (left) and difference (right) patterns.

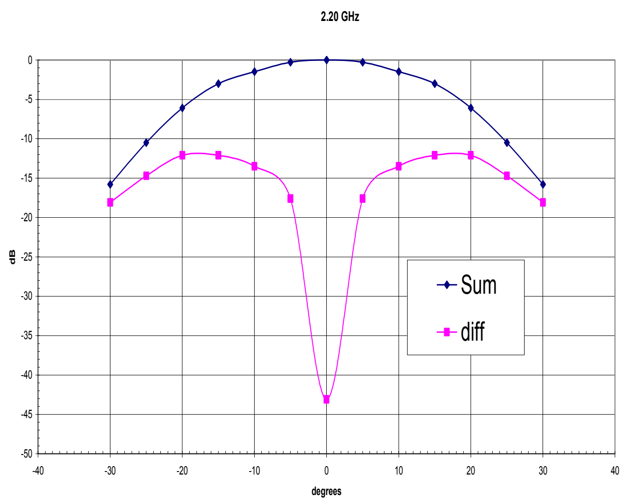

Fig.7 The measured sum and difference patterns of the monopulse feed at 2.20 GHz.