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Design and Study of the Elevation Difference Channel Feed of the Single Aperture Monopulse Feed System

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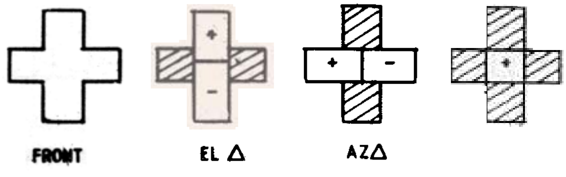
ABSTRACT

The technique to generate the higher order modes TE_{11} and TM_{11} in the square waveguide, required for the E plane error single channel feed in the single perture monopulse feed system, has been presented and the appropriate assembly for this purpose has been designed in the 8.5–9.0 GHz frequency band. The assembly can be incorporated as an E plane error signal channel feed in the design of a single aperture monopulse feed system. The features of the design are a suppressed cross-polarised component of the radiation field and a deep null in the E plane pattern at the boresight axis of the feed. A qualitative explanation for the behaviour of the feed has been presented.

1. INTRODUCTION

In a monopulse tracking radar, two types of output signals from the antenna, one each for the sum and difference channels, are required to determine the angle in one plane. These two channels have altogether different characteristics. The feed of the antenna capable of catering for this type of special requirement must generate different desired field configurations. These are shown in Fig. 1, for an ideal feed.



The field configurations depicted in Fig. 1, cannot be achieved by a single mode conventional horn which has a sinusoidal aperture distribution for the dominant mode

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TE_{10} only. A cluster of horns alongwith a microwave netwrok to combine the output of the different field configuration were used as a feed. All the channels in the cluster feed cannot be optimised simultaneously due to certain inherent limitations of the conventional horn antenna as well as due to the configuration of the feed. And, therefore, the efficiency of the feed was found to be poor. The complexity was more due to the microwave network which rendered it unsuitable for broadband purposes. One of the requirements of the precision tracking is the boresight stability which is also affected due to the complex nature of the feed.

Higher order waveguide modes can be incorporated in a conventional horn feed to develop a single aperture feed with monopulse capabilities. This technique helps in improving the efficiency of the feed in all respects. Many workers[1-3] have utilised this technique to develop the monopulse feed with improved results. For the sum channel, TE_{12} and TM_{12} modes were used alongwith the fundamental mode TE_{10} while the difference channels utilised the TE_{11} and TM_{11} modes for the E plane error signal and the TE_{20} mode for the H plane error signal.

In this paper, the technique to generate the combined nett effect of the higher order modes TE_{11} and TM_{11} required for the E-plane error signal in the monopulse single aperture feed is described in the 8.5–9.0 GHz frequency band. The design has been performed in such a way so that it can be incorporated in the final design of the single aperture multimode feed with monopulse capabilities.

2. DESIGN CONSIDERATIONS

The E field aperture distribution of the higher order modes TE_{11} and TM_{11} in square waveguide is shown in Fig. 2. The degenerate modes and their cross-polarised components (horizontal plane components) are exactly equal and opposite to each other. Therefore, the resultant E field aperture distribution of these two modes will have only the vertically polarised components as depicted in the Fig. 2. It is quite

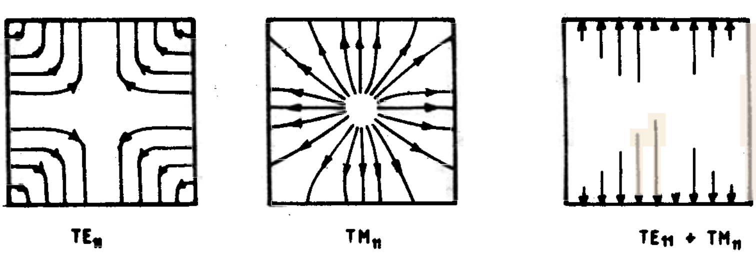

Figure 2. Aperture field distribution of higher order modes TE_{11}, TM_{11} and $TE_{11} + TM_{11}$ in a square waveguide.

clear from this type of aperture distribution that its radiation pattern in the H plane will be zero through out while the E plane will have a desired error signal pattern with null at a boresight axis of the antenna. The efforts have been made to generate the resultant aperture distribution rather than the individual modes to get the desired radiation pattern. The idea is to generate the E field distribution like TM_{11} mode and suppress the cross-polarised E field components of this mode to an appreciable extent by suitable methods to get the desired aperture field distribution.

The dimension of the square waveguide was so chosen that it could propagate freely the TE/TM_{11} modes through out the desired frequency band. Since the aim is to develop the assembly to generate the TE/TM_{11} modes to cater for the E-plane error signal in the single aperture multimode horn feed with monopulse capabilities, the propagation of other higher modes as TE/TM_{12} and TE_{20} required for other channel signals of the feed have also been taken into account in deciding the dimension of the waveguide.

The horizontal cross section from the middle of the square waveguide containing the assembly to generate the desired aperture field distribution is shown in Fig. 3.

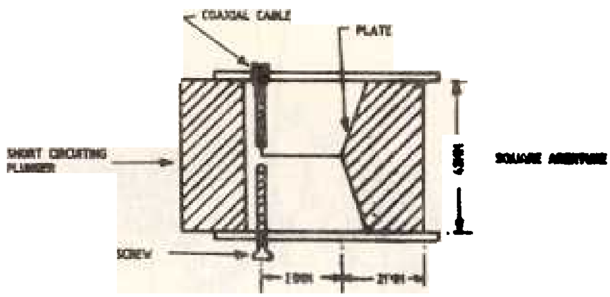

Figure 3. Schematic of the assembly to generate the resultant effect of higher order modes TE_{11} and TM_{11} in the square waveguide

The assembly consists of a plate, the inner conductor of the coaxial line, and a screw where the later two act as a probe and a post respectively. The waveguide has been closed from the probe side to ensure the flow of energy only towards the open end. The distance of the closed end from the probe is so adjusted that it reinforces the energy in the forward direction. The length of the post in the waveguide should cater for the minimum VSWR in the desired frequency band. The plane of the plate and the probe should be same and it should divide the waveguide into two halves. Thus it will ensure equal and opposite division of energy with vertical polarisation and suppress horizontally polarised components which are considered parallel to the plane of the plate. The dielectric of the coaxial cable has been projected up to the middle of the transverse length of the waveguide to give the extra support to the probe.

3. RESULTS AND DISCUSSION

The electrical evaluation of the designed antenna at 8.5–9.0 GHz frequency band has been carried out in the anechoic chamber of the laboratory. The VSWR of the antenna has been measured with the help of a network analyser and its maximum value is 3.00 in the above frequency range. The length of the probe along the boresight axis of the waveguide has been varied alongwith the length of the plate and the E plane patterns in the desired frequency band have been taken for each set. Since the probe will also give rise to the unwarranted E field with horizontal polarisation, the E plane cross polarised patterns have also been recorded to see their level in comparison to the E plane error signal peaks. The position of the post in the each set has been adjusted for the best possible results and the best combination of the probe length and the plate length to cater for the desired radiation pattern has been found out. The power patterns for the case of the best combination are shown in the Fig. 4.

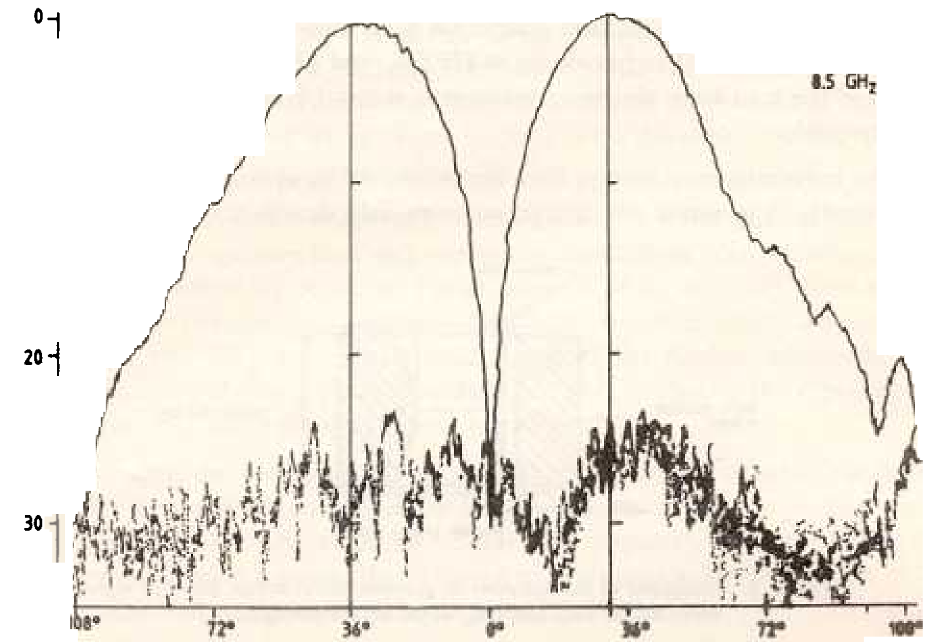

Figure 4(a) E plane and its cross-polarised radiation patterns of the antenna at frequency in 8.5 GHz band.

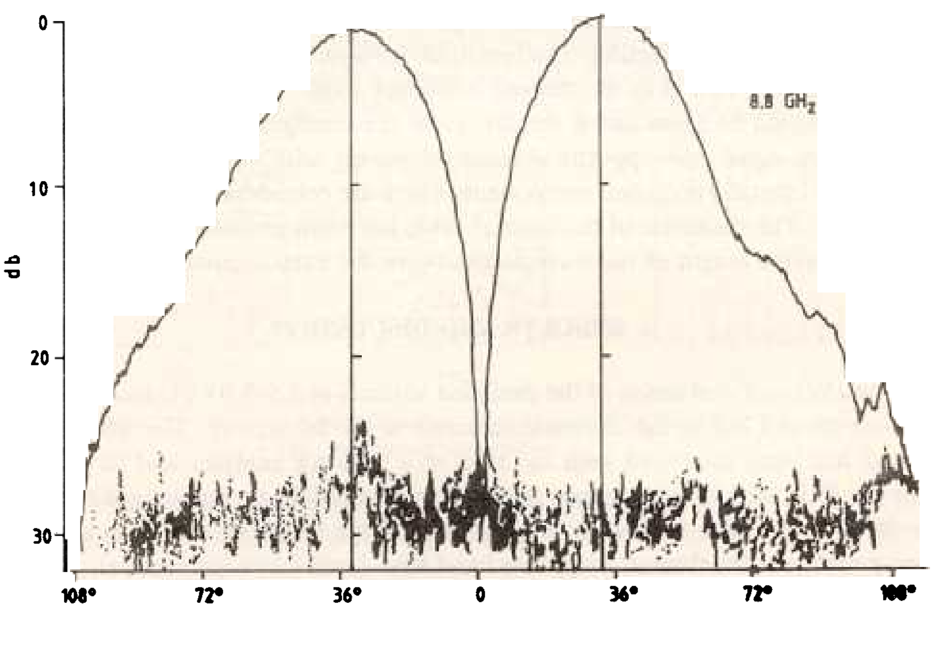

Figure 4(b) E plane and its cross-polarised radiation patterns of the antenna frequency in 8.8 GHz band.

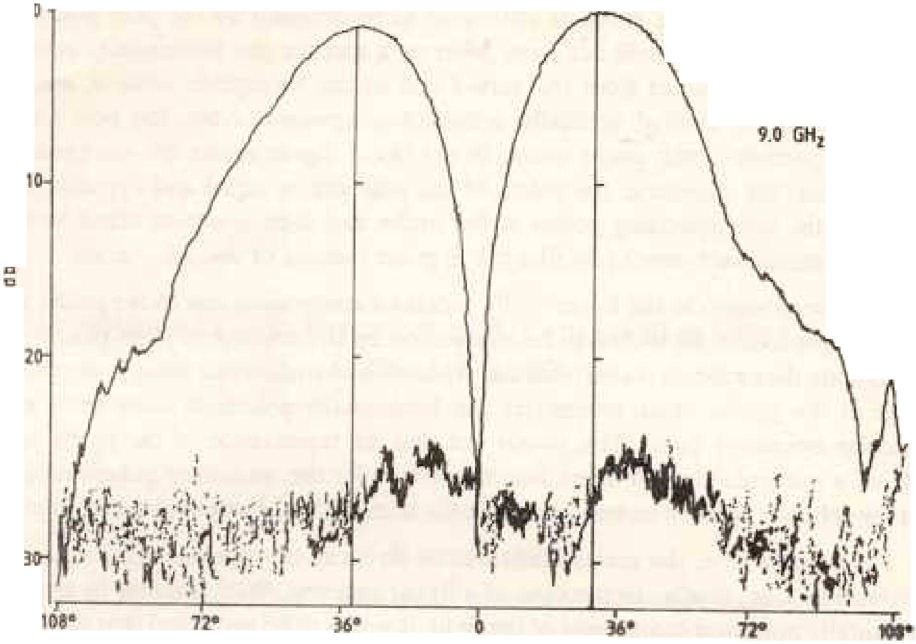

Figure 4(c) E plane and its cross-polarised radiation patterns of the antenna at frequency in 9.0 GHz band.

The features of the radiation pattern of the antenna are mentioned as below :

(a) The desired E plane error signal pattern is obtained in which the null along the boresight of the antenna is down by about 30 dB in the entire frequency band. The null is thus appreciably deep.

(b) The position of the null in the error signal pattern is almost along the boresight axis of the antenna. The stability of its angular location is thus excellent which is otherwise not found so good in conventional monopulse feeds. This stability helps in improving the accuracy of the angular tracking.

(c) The maximum signal level of the signal in the *E* plane cross polarised pattern is about 25 dB down from the peak of the matched polarised pattern. It has thus been suppressed by an equally good amount.

The above features of the antenna patterns clearly show that the assembly inside the waveguide is generating the combined nett effect of the desired higher order modes namely TE_{11} and TM_{11} required for the *E* plane error signal in the multimode monopulse feed with single aperture.

The behaviour of the assembly in the waveguide to cater for the desired rediation pattern can be understood as follows.

The transverse portion of the probe will mainly generate the horizontally polarised *E* field component while the portion of the probe along the boresight axis of the waveguide will generate *E* field like TM_{11} mode which has both the polarisations. The contribution to the horizontally polarised component of the field due to the transverse portion of the probe is attributed to be arrested by the post placed just opposite to it. The post will act some what as a sort for the horizontally polarised reflected travelling waves from the sorted end of the waveguide while it will have little effect on the desired vertically polarised component. Also, the post and the transverse portion of the probe seems to act like a dipole inside the waveguide. In this situation, the current at the points of the post will be equal and opposite to the current at the corresponding points of the probe and their resultant effect in the *E* plane will cancel each other just like the E plane pattern of the TE_{20} mode.

The contribution to the horizontally polarised component due to the probe along the boresight axis is attributed to be suppressed by the horizontal plate placed so as to terminate the probe. It seems from the experimental studies that there is an optimum length of the probe which suppresses the horizontally polarised component in the particular frequency band. This points out that the termination of the probe by the plate of a particular length alone acts like a sort for the undesired polarisation in a frequency band. This can be understood on the basis of the following consideration.

For a thin probe, the current distribution on it can be approximately assumed as a sinsusoidal one, similar to the case of a linear antenna. With the aim to arrest the horizontally polarised component of the field, it seems to be preferred that the current distribution near the terminated end of the probe should have a negative slope of the sinusoidal distribution. In this way, the tendency to generate the field by the probe would be towards the decreasing side. When such a probe is terminated by a horizontal plate of a particular length, it acts as a sort for the undesired horizontally polarised component of the field. This view point is seemed to be in agreement with experimental results where the probe length and the plate length for the optimum case is approximately λ_g and $\lambda_g/2$ respectively at the centre frequency.

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REFERENCES

1 Howard, D.D., IEEE Intern. Cov. Military Electron Conf. Proc., (IEEE Press, New York), 1964, p. 259.

2. Profera, C.E. Jr. & Yorinks, L.H., *Suplement IEEE Trans. Aerospace Electron Systems, AES-2* (1966), 314.

3. Mikulich, P., Dolusic, R,, Profera, C., & Yorinks, L., IEEE G-AP Intern. Antenna Propagat. Symp. Record, (IEEE Press, New York), Sept. 1968.