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Experimental Characterisation of Moreno Cross-Slot Couplers for Blass Matrix Design

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ABSTRACT

This paper presents the experimental characterisation of Moreno cross-slot coupler which is the basic building block of multiple beam forming network (Blass matrix). The lack of exact theory of such coupler requires extensive experimental evaluation. A novel test jig has been designed, fabricated and tested for this purpose. The experimental results for different scattering parameters are presented.

1. INTRODUCTION

Present and future radar systems require both surveillance and tracking functions to be performed at angular rates exceeding those of the existing radar systems. Multibeam antennas (MBA) have great significance for such applications. Through MBA, many beams can be formed from a single radiating aperture using a suitable beam former. The main constituents of MBA are radiating elements (antenna) and beam forming network (BFN). The latter is a circuitry that divides the input power among the beam port and/or combines the signal received by the beam port. BFN using multiple beam forming Network (Blass matrix) has found applications in MBA design. Moreno coupler is the building block of Blass waveguide multiple beam forming network. An efficient design of Blass matrix requires accurate characterisation of individual Moreno cross-slot directional couplers. Moreno coupler, as the name suggests, was first introduced by Moreno[1]. Since then, many researchers have carried out significant work. Different approximate theories are available. Theory developed by Surdin[2] can only hold for off-resonance slots. A more general theory was derived by Lewin[3], which holds fairly good for slots near-resonance.

An approximate analysis based on Bethe's small aperture coupling theory for coupling between two waveguides, through an aperture in the common broad wall, is given by Levy [4]. Measured electric and magnetic polarisabilities of various apertures and size are given by Cohn[5] who has also proposed frequency correction and wall thickness correction factors for coupling equation[6]. Frequency correction factor is obtained by representing coupling aperture between wavguides as loss-less impedance, which obeys Foster's reactance theorem. The impedance was modified by the factor $(1-f^2/f_0^2)$, which takes slot resonance into account, where f_0 is the resonance frequency of slot. Thickness correction factor is obtained by treating aperture as finite length waveguide beyond cutoff. Bethe's theory assumes coupling by equivalent electric and magnetic dipoles in the plane of aperture and uses constant field over the entire

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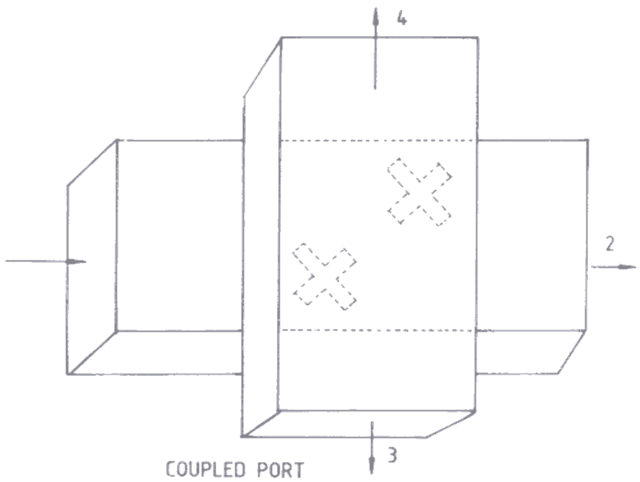

Figure 1. Moreno cross-slot coupler

aperture. Levy[7] has suggested an additional correction factor for coupling equation which is obtained by taking average value of field over the aperture.

The results obtained using above theories deviates substantially from experimental results. Theoretical limitations in predicting the complete set of scattering parameters accurately, forces experimental characterisation of Moreno couplers. The design of Blass matrix requires a range of coupling values from -3 to -50 dB. In this paper, an attempt has been made to characterise Moreno cross-slot couplers experimentally by designing novel test fixtures in different frequency bands.

2. MORENO COUPLER THEORY

Moreno coupler is made of two orthogonal rectangular waveguides kept one over the other having a common broad wall. There are two cross-slots with spacing of $\lambda_g/4$, cut diagonally on the common broad wall of two waveguides, as shown in Fig 1. The power coupled by each cross-slot is approximately equal in amplitude and phase. The individual cross-slot couple more power in one direction compared to the other direction. The directivity of Moreno coupler is less dependent on frequency and spacing between the slots, because of the self-directive property of cross-slots. The coupling can be changed by changing the length of the slot.

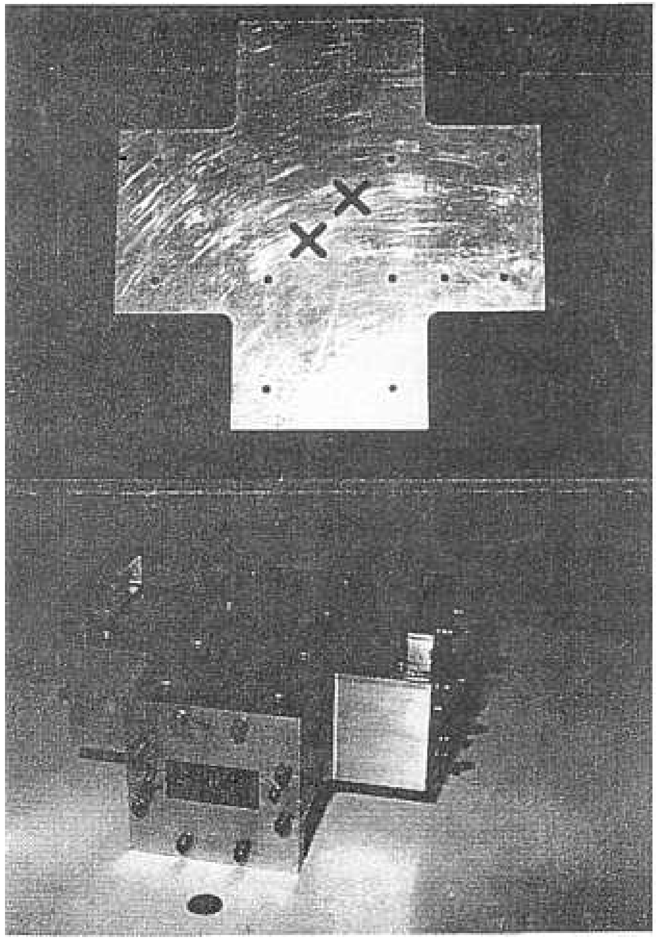

Figure 2. Coupler test jig and insert plate

3. EXPERIMENTAL EVALUATION

A novel test fixture containing two blocks with coupling insert plate was devised. The dimensions of the waveguides were obtained by machining two

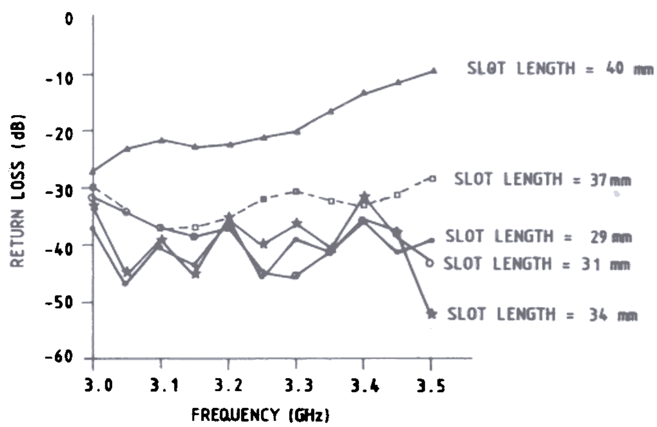

Figure 3. Frequency *vs* return loss for different slot lengths

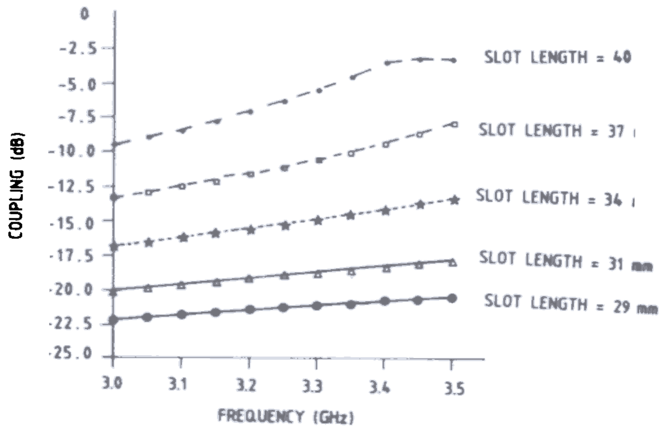

Figure 4. Frequency *vs* coupling for different slot lengths

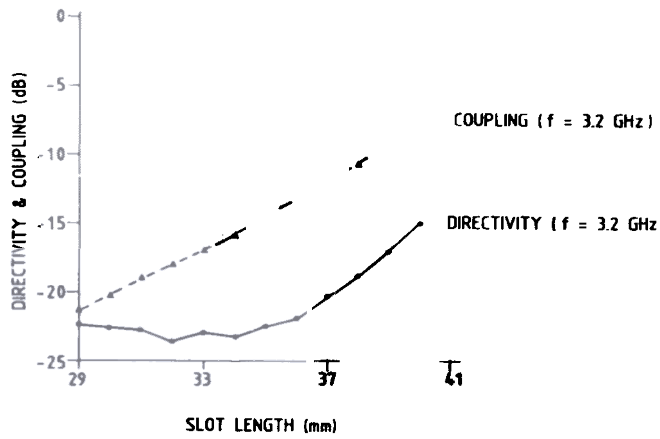

Figure 6. Slot length *vs* coupling and directivity

solid aluminium blocks. In the first block, channel of required waveguide dimensions, a_m was machined. In the second block, channel of required branch waveguide dimension, a_b was made in such a manner that when two blocks are connected together, the channels are orthogonal to each other. To have a common wall between two blocks, a coupling insert plate having the same geometry as that of the block was designed. Crossed-slots of required dimensions are machined on the coupling insert plates. To obtain more than one data point, the test fixture accommodates several crossed-slot geometries by virtue of different insert plates. Indexing pins of appropriate dimensions are provided for a better match among the main waveguide, coupling insert plate and branch waveguide. Apart from this, a number of screws at several places are used to avoid any leakage. Photograph of a test fixture with coupling insert plate is shown in Fig 2. The accuracy in results obtained by this coupler has already been established for other types of coupling slots[8-10], where experimental data matches to those of moment method results. The test fixture can be viewed as a four-port transmission line network. Extensive measurements are carried out using HP-8510 automatic vector network analyser. The network analyser is calibrated for two-port measurements using waveguide calibration kit. The input and output of the coupler are connected to network analyser using waveguide to coaxial adapter. The other two ports of the coupler are terminated using matched loads. The coupling insert plates for different slot lengths, widths and thickness are fabricated. Complete sets of scattering parameters are measured for all coupling insert plates over a frequency band of interest. The measured data for 101 frequency spots are transferred into a PC using GPIB interface and stored as a data file for further processing.

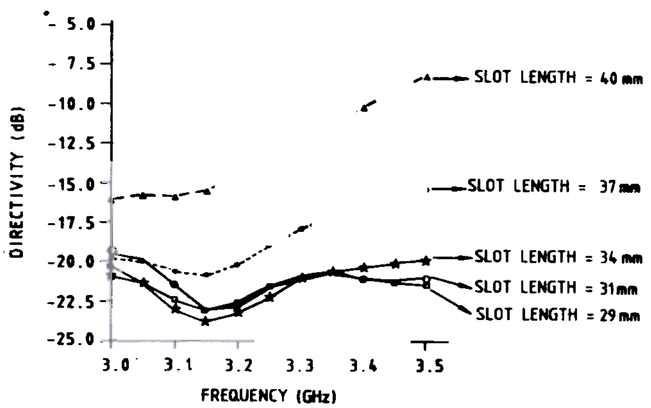

Figure 5. Frequency *vs* directivity for different slot lengths

4. PRACTICAL OBSERVATIONS

Different plates with varying slot dimensions have been tested. Return loss of the coupler is very good (< –25 dB) over a wide band of frequency (>500 MHz) in the case of loose coupling. At tight coupling levels, the return loss becomes poor at higher side of the design frequency. The variation in coupling and directivity with frequency is less at loose coupling levels and is more at tight coupling levels. Various curves of return loss, coupling and directivity for different slot lengths are shown in Figs 3, 4, and 5. Variation of coupling and directivity as a function of slot length is also plotted in Fig. 6.

5. CONCLUSION

Suitable test jig is devised to characterise the Moreno coupler experimentally. Extensive measurements were performed for slots varying in length, width and thickness. A huge data bank for various scattering parameters required to design beam forming network for multiple beam antenna has been prepared. Many of the properties of this type of coupler have also been validated by this experiment.

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