A Butler Matrix Design for Directional Antenna

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Abstract – This paper demonstrates an 8 X 8 Butler Matrix design that does not employ cross-overs. The Butler Matrix was manufactured on a single side of Printed Circuit Board (PCB) and is intended for use with a low-profile C-band directional antenna array. This solution provides an effective methodology for electronically switching beam states of a planner distributed array where typical applications of active phase shifters would either be cost prohibitive or are unnecessary to meet the technical requirements. This design makes use of a series of quadrature hybrid couplers made up of microstrip line circuit board. Test results show that the Matrix efficiently produces the necessary power and phase distribution to each output port allowing the antenna array to show 8 distinct beam states.

Keywords – Butler Matrix, C-Band, and Directional Antenna.

I. INTRODUCTION

Many techniques can be used to give an array multi-beam radiation pattern capabilities. One such technique is called the Butler Matrix, which consists of quadrature hybrid couplers and fixed phase shifters [1]. The target application was designed using eight sub-arrays to consequently provide eight beam states. Each sub-array has its own input port to connect to the output port of the Butler Matrix. When one of the eight input ports of the Butler Matrix is excited, the Matrix provides equal power and staggered phase distribution across all output ports resulting in a distinct beam.

The single-layer Butler Matrix design was selected over several alternative passive beam-forming network concepts due to its unique characteristics. For example the Rotman Lens which provides the same functionality as the Butler Matrix was not used due to its large footprint and higher relative insertion loss. Also considered were active beam-forming techniques such as phase shifters, which provide high fidelity beam steering and narrow beam-widths but are unnecessarily precise and costly for most terrestrial communications networking applications.

II. THE DESIGN AND RESULTS

A. *THE DESIGN*

The designed Butler Matrix block diagram is displayed in Figure 1. Shown are the fixed phase shifters and the 90-degree hybrids, which are fabricated using a precise milling tool on one side of the copper PCB. The phase shifters and the 90-degree hybrids are made of 50-Ohm microstrip lines without crossovers, which typically results in added insertion losses. Located on the other side of the PCB is the copper ground plane. The eight output ports of the Butler Matrix are connected to the eight antenna sub-arrays and the eight input ports are connected to the inputs of the RF feeds.

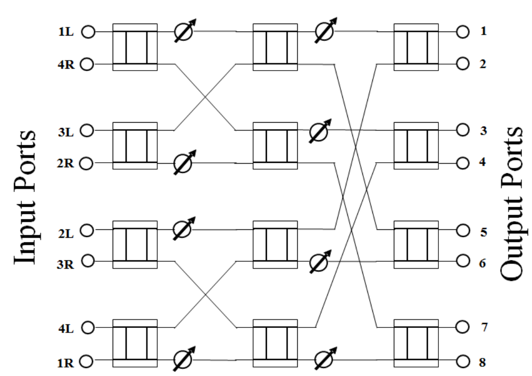
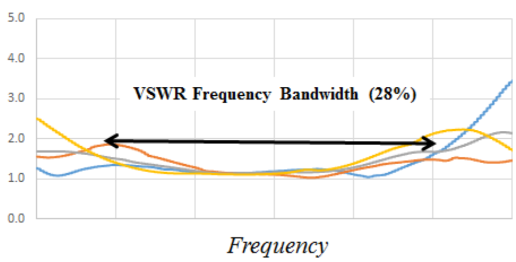
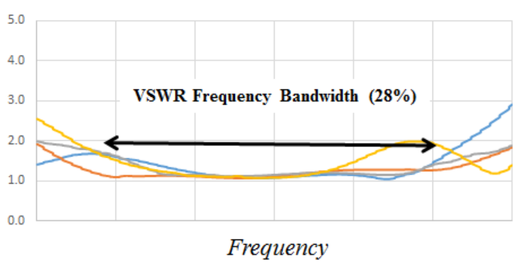


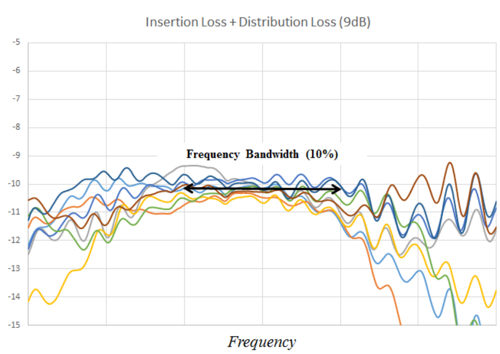
Figure 1. The designed Butler Matrix block diagram

B. THE MEASURED RESULTS

The designed single-layer 8 X 8 Butler Matrix prototype was measured in the C-Band frequency range. The realized VSWR of 2.0 spread across 28% of the frequency band and is shown in Figure 2 (a) and (b). The measured amplitude and phase distributions are also shown in Figure 2 (c) and Figure 2 (d), individually.







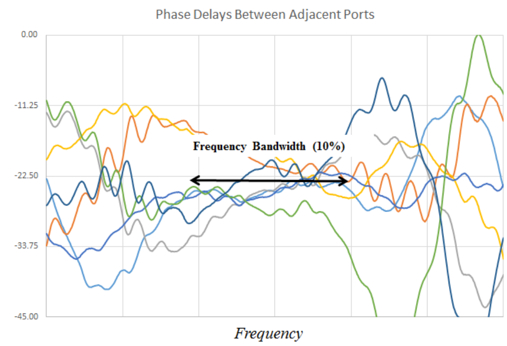


Figure 2. Measured VSWR (a) and (b), Insertion Loss (c), and Phase Distributions (d).

III. CONCLUSIONS

With an average insertion of 1.2dB across 10% of the frequency band and phase distribution errors of +/-11.25 degrees, the designed Butler Matrix has met the performance requirements necessary to feed an antenna array and provide eight distinct beam states. Using a total of four Butler matrices, each feeding a single antenna array, three hundred and sixty degrees of RF coverage can be obtained. This distributed model allows for a reduced antenna signature while maintain system performance.

REFERENCES

[1] Constantine A. Balanis, Antenna Theory, John Wiley & Sons, Inc.