Double-Layer Rectangular-Waveguide Structure for Butler Matrix using Slit Coupling on the Broad Walls

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The authors proposed full double-layer configuration using rectangular waveguides of Butler matrix, where the hybrids are used with broad-wall slot coupling and the layers are changed only at places for the phase shifters as shown in Fig.1 (J.Hirokawa et al., Proc. 32nd European Microwave Conf., M36-3, 2002). This paper proposes to use slits all over the broad-wall to get wide bandwidth not only in the hybrids (F.Arndt at al., IEEE Trans. Microwave Theory Tech., 33, 95-104, 1985) but also in the phase shifters. The configuration is modified as shown in Fig.1 by including the phase progression in the hybrids and the phase delay in the phase shifters.

Fig.1 shows the block diagram of Butler matrix, for 8 beams as an example. The name of the input ports at the bottom express the beam direction (L: left, R: right, 1: smaller tilting angle – 4: larger one) (J.Butler and R.Lowe, Electron. Des., 9, 170-173, 1961). In the broad-wall coupling for the hybris, the output port at the differenet waveguide has 90-degree phase progression in comparison with that in the same waveguide in principle. However the phase shiter using the silts all over the common broad-wall of two shorted rectangular waveguides as shown in Fig.2 gives only some delay. It is difficult for it to give phase progression. Blocks of required phase shifts (+45, +45, 0, 0) in degrees in the conventional configuration should be replaced with (0, 0, –45, –45) as shown at Part (a) in Fig.1. The full double-layer configration can be still kept after this replacement. Other blocks of required phase shifts (+67.5, 0, 0, +22.5) should also be replaced with (–22.5, –90, –90, –67.5) as shown at Part (b) in Fig.1. –90-degree phase shiters will be obtained by installing corrugations at the bottom in a rectangular waveguide.

The phase shifter in Fig.2 is analyzed using the mode matching method. A –45-degree model is designed to supress the reflection below –40dB and to have a change of 4.8 degrees in the transmission phase over 3.9 – 4.1GHz as shown in Fig.3 by using genetic algorithm and modiled Powell method together (M.Okamoto et. Al, Math. Comp., 91, 63-72, 1998).

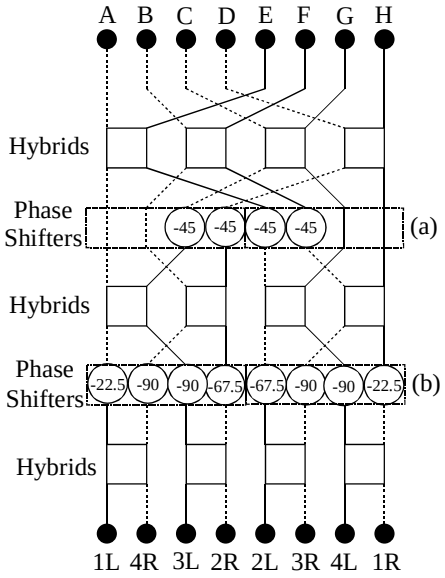

Fig.1: Block diagram of Butler Matrix (Solid: upper layer, dotted: lower one)

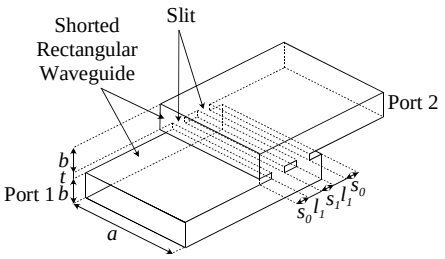

Fig.2: Phase shifter

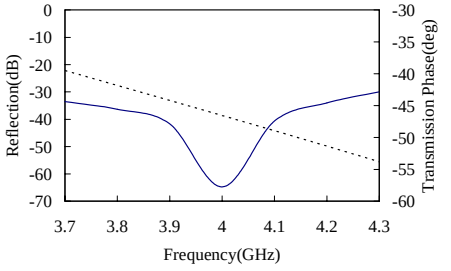

Fig.3: Reflection (solid) and transmission phase (dotted)