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Abhaikumar et al.

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(54) **DEVICES AND METHODS FOR PHASE SHIFTING A RADIO FREQUENCY (RF) SIGNAL FOR A BASE STATION ANTENNA**

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(58) **Field of Classification Search**

USPC 455/63.4, 80, 81, 107, 111; 343/771, 343/768

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,667,714	B1 *	12/2003	Solondz	342/368
2003/0043071	A1 *	3/2003	Lilly et al.	342/368

(Continued)

FOREIGN PATENT DOCUMENTS

EP	1170817 A1	1/2002

OTHER PUBLICATIONS

Hwang, R., "A Low-Cost Electrical Beam Tilting Base Station Antennas for Wireless Communication System," IEEE Trans. on Antennas and Propagation, vol. 52, Jan. 2004, pp. 115-121.*

(Continued)

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(57) **ABSTRACT**

Methods and devices for phase shifting an RF signal for a base station antenna are provided. The device includes a transmission line that has a stationary ground plane coupled to the top of a substrate and a signal line on the bottom of the substrate. The signal line has an input port and an output port. The input port receives the RF signal with a certain phase and travels across the bottom of the substrate to the output port. The RF signal has a different phase at the output port because defected ground structures etched on the stationary ground plane shift the phase of the RF signal. In addition, the device includes a movable ground plane that may cover a portion of the defected ground structures, the substrate, and the stationary ground plane such that the moveable ground plane further adjusts the phase of the RF signal.

20 Claims, 9 Drawing Sheets