COPLANAR WAVEGUIDE, A SURFACE STRIP TRANSMISSION LINE SUITABLE FOR NONRECIPROCAL GYROMAGNETIC DEVICE APPLICATIONS

Cheng P. Wen
RCA Laboratories

SUMMARY

A novel integrated circuit transmission line with all conducting elements on the same side of a dielectric substrate (coplanar waveguide) has been demonstrated as a suitable structure for fabricating nonreciprocal microwave magnetic devices. As shown in Figure 1, the coplanar waveguide (CPW), consists of a strip of thin metallic film deposited on the surface of a dielectric slab with two ground electrodes running adjacent and parallel to the strip on the same surface. The r-f electric field between the center conductor and the ground electrodes tangential to the air-dielectric boundary produces a discontinuity in displacement-current density at the interface, thus giving rise to an axial as well as transverse component of r-f magnetic field shown in Figure 2. These r-f magnetic field components provide the elliptical polarization needed for nonreciprocal gyromagnetic devices. The coplanar configuration of the conducting elements permits easy connection of external shunt elements such as active devices in hybrid integrated circuits. It is also ideal for shunt connection of various elements in monolithic microwave integrated circuit systems.

The characteristic impedance, Z_o, of a coplanar waveguide fabricated on dielectric half planes with relative dielectric constant ϵ_r has been calculated as a function of the ratio a_1/b_1, where $2a_1$ is the width of

NOTES

the center strip and $2b_1$ is the distance between the two ground electrodes. A zeroth-order, quasi-static approximation is employed, leading to results shown in Figure 3. The three data points on the same figure are derived from experimental results obtained on coplanar waveguides fabricated on 0.025 inch thick substrates of relative dielectric constant $\epsilon_r = 9.5$, 16 and 130 respectively. The measured characteristic impedance agrees well with predictions based on calculations when the relative dielectric constant of the substrate is 16 or higher. Incidentally, the characteristic impedance of a coplanar waveguide is relatively independent of the thickness of the dielectric substrate provided it is larger than the width of the slots between the center strip and the ground planes.

Measurements made on a 16.6 Ω CPW fabricated on a rutile substrate ($\epsilon_r = 130$, $a_1/b_1 = 1/3$, center conductor width is 0.025 inch, thickness of gold films is 2 microns, thickness of dielectric substrate is 0.025 inch), yielded a Q of 173 at 4 GHz, corresponding to an attenuation of only 0.158 db/wavelength.

Matching of a 50 Ω coplanar waveguide into a 50 Ω coaxial line has been achieved over a broad frequency range (up to 12 GHz). The coax-to-CPW transition is made with an OSM connector whose inner conductor contacts the center strip of the coplanar waveguide. Relatively small change in characteristic impedance has been observed.

Nonreciprocal gyromagnetic devices such as resonant isolators and differential phase shifters have been fabricated by attaching ferrimagnetic slabs at the air-dielectric interface between the conductors. A transverse d-c magnetic field parallel to the surface of the substrate is required to provide appropriate bias conditions. Performance of a coplanar waveguide ferrimagnetic resonant isolator built on the surface of a rutile single crystal is shown in Figure 4. These preliminary results show that an isolation of 37 dB at the center frequency of 6 GHz has been achieved while the forward attenuation is below 2 dB. Overall length of the device, including a quarter wave transformer at each end, is 0.8 inch. A differential phase shifter, 0.8 inch long, yielded an average differential phase shift of 45° with less than 1 dB insertion loss in either direction when tested between 5.6 and 7.1 GHz. These results serve to demonstrate the possibility of integrated microwave nonreciprocal magnetic devices in coplanar waveguide form.

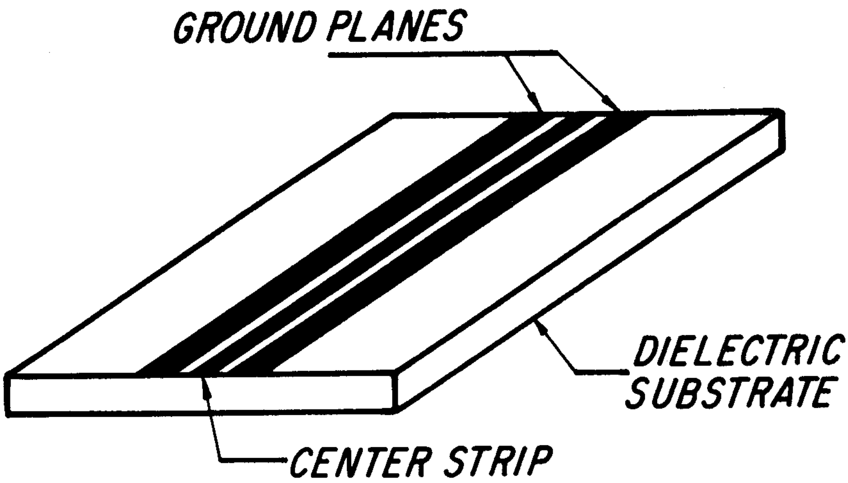

Figure 1 - Coplanar Waveguide, A Surface Strip Transmission Line

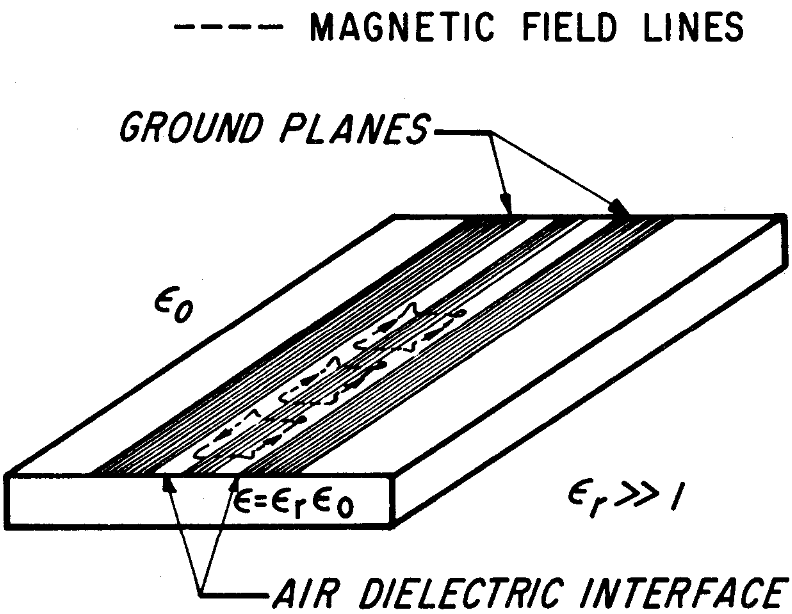

Figure 2. RF Magnetic Field Configuration in a Coplanar Waveguide

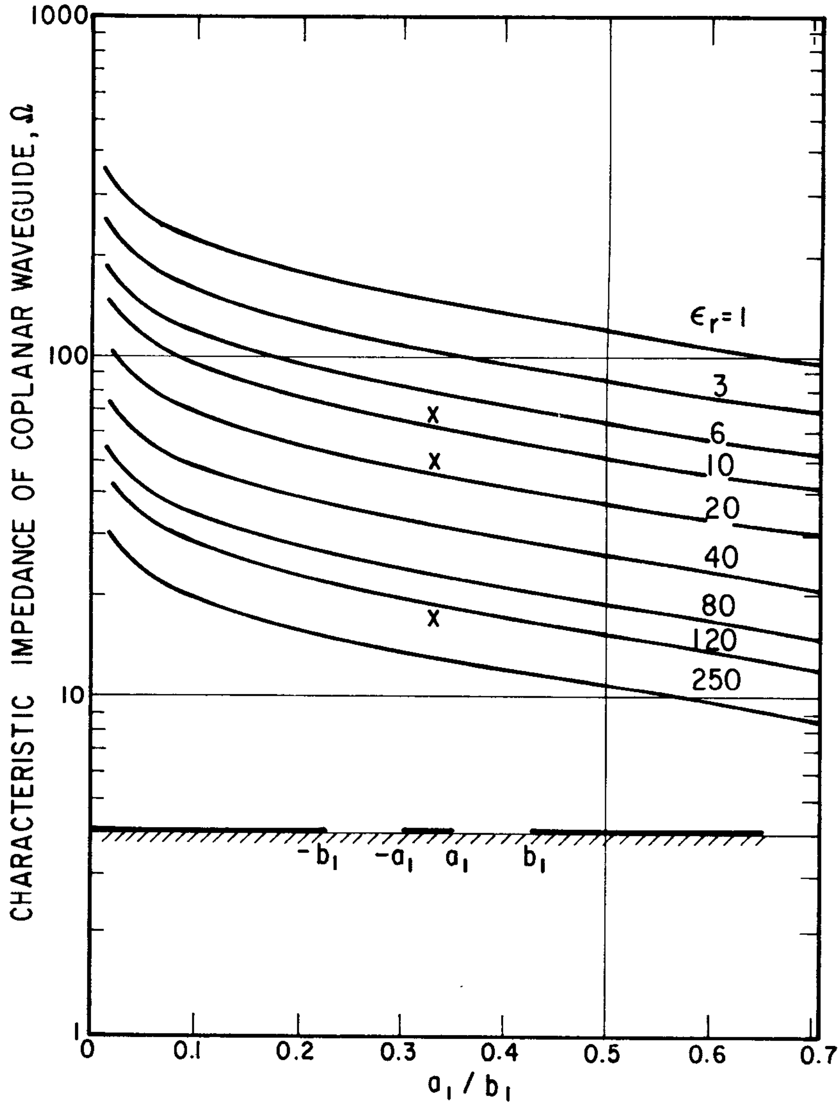

Figure 3 - Characteristic Impedance Z_o of Coplanar Waveguides as a Function of the Ratio a_1/b_1 with Relative Dielectric Constant ε_r as a Parameter.

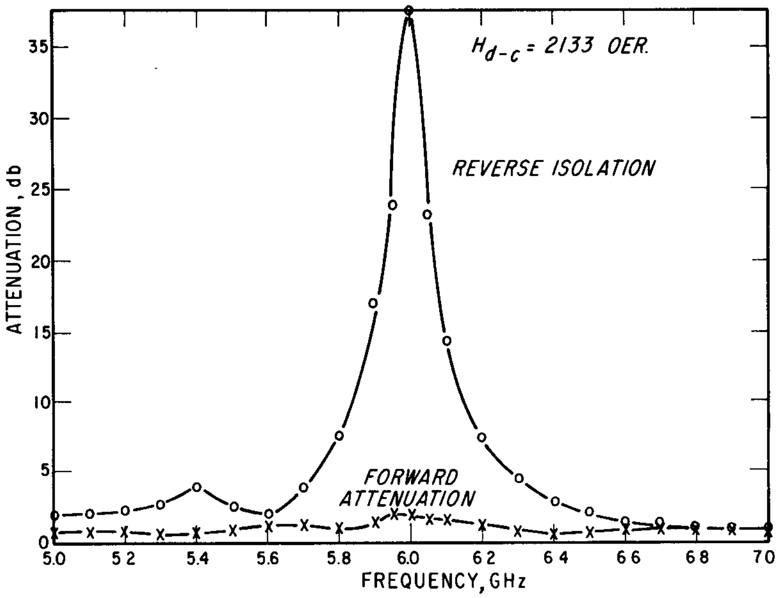

Figure 4 - Performance of a Coplanar Waveguide Ferrimagnetic Resonant Isolator on a Single Crystal Rutile Substrate.

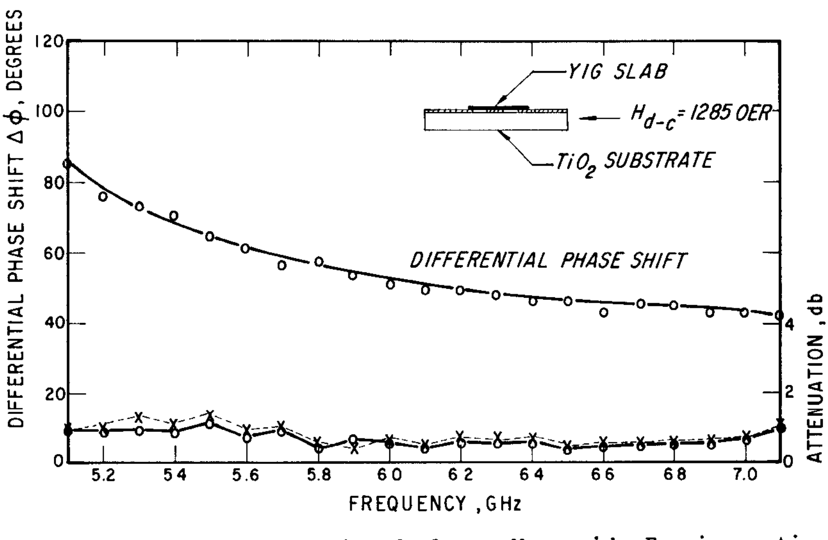

Figure 5 - Performance of a Coplanar Waveguide Ferrimagnetic Differential Phase Shifter on a Single Crystal Rutile Substrate.