# VARIABLE POLARIZATION FERRITE ANTENNA

Daniel S. Dunn, Matthew S. Telep, Eugene P. Augustin
TECHNICAL SYSTEMS ASSOCIATES, INC
1900 Central Florida Parkway
Orlando, FL 32837-9290
(407) 857-3235

## KEY WORDS

Polarization, Ferrite, Antenna, Faraday

## ABSTRACT

This paper describes a ferrite antenna that can produce any polarization on the Poincaré sphere over the frequency range of 9.0 to 11.4 GHz by utilizing Faraday rotation and a quarter-wavelength phase shifter. All possible polarizations of the electromagnetic wave are achievable with this antenna which includes linear, circular and elliptical polarizations. Any tilt angle of elliptical polarization and any orientation of the linear polarization can be achieved as well. The polarization of the ferrite antenna can be electronically switched to a different polarization instantly without the use of moving parts. An automatic data acquisition system was designed and built to fully analyze the antenna' s characteristics.

## INTRODUCTION

A single antenna that can provide all possible polarizations on the Poincaré sphere and can switch instantly between the different polarizations has several applications in both military and commercial markets. The polarization is electronically controlled and can be changed instantly from its current polarization to the next desired polarization. This ferrite antenna has potential applications as a feed for a reflector, an airborne jammer, or simply as a test antenna in the laboratory.

The polarization of the antenna is controlled simply by the amount of DC current applied to the Faraday rotator coils It has the ability to switch polarizations very quickly, limited only by the inductance of the coil. The reliability of the unit is increased significantly because there are no moving parts. The ferrite antenna is a small compact unit, slightly larger than the waveguide itself.

The original design goal was to achieve performance over the frequency range of 9.0 to 10.5 Ghz. Analysis of the final design revealed an operational bandwidth from 9.0 to 11.4 GHz.

## ANTENNA DESIGN

The ferrite antenna consists of two Faraday rotators with a quarter-wavelength phase shifter between them. A cross sectional view of the antenna is shown in Figure 1. A guided wave incident upon the antenna's input port undergoes a transition from WR90 rectangular waveguide to a dielectrically loaded circular waveguide. It travels through the input Faraday rotator, the quarter wavelength phase shifter, the output Faraday rotator and is then emitted into free space through a dielectric rod aperture. The antenna is 3.25 inches in diameter with an overall length of 8.12 inches.

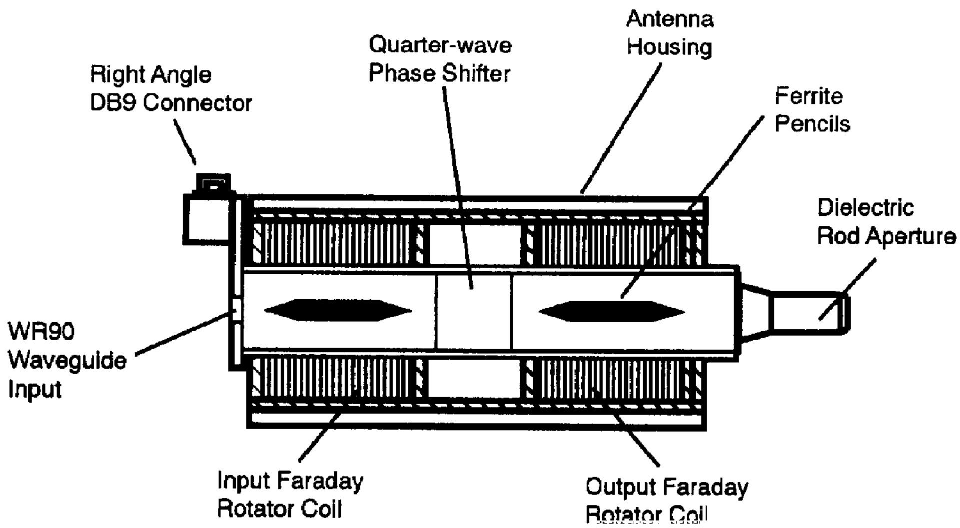



Figure 1. Configuration of the Variable Polarization Ferrite Antenna

A linearly polarized wave entering the antenna from the WR90 waveguide can be rotated a nominal ±60° from its reference position, depending on the frequency of operation, by the input Faraday rotator. The rotation produces the proper orientation of the E-field with respect to the phase shifter section. Depending on the input E-field orientation, the output of the phase shifter will produce linear, RHC, LHC, RHE or LHE polarization. Finally, the output Faraday rotator introduces the desired tilt angle for elliptical polarizations or simply a different orientation for linear polarizations by rotating the wave through a range of ±60°.

The circular waveguide is loaded with a teflon dielectric which also holds the ferrite pencils in place within each respective coil. Teflon was chosen because of its low loss tangent, ease of machining, availability and cost. The quarter-wavelength phase shifter was designed by machining two symmetric cut-outs from the sides of the cylinder-shaped teflon inside the waveguide. The teflon was reduced until the proper phase characteristics were achieved over the frequency range of operation.

The E-field rotation of a Faraday rotator is nonreciprocal due to the ferrite's hysteresis. The ferrite pencils have a hysteresis loop which must be considered when trying to achieve repeatable antenna measurements. It was discovered that results varied depending on previous applications of coil currents. In order to achieve the desired repeatability it was necessary to eliminate the "memory" of the ferrite. This was accomplished by applying a degaussing voltage was applied to the coils in order to depolarize the ferrite and establish a baseline reference.

The degaussing voltage is a simple decaying square wave with an average of zero volts. The peak voltage of the decaying square wave saturates the ferrite and then exponentially reduces to zero. The degauss time is approximately 5 milliseconds and is limited by the inductance of the Faraday rotator coil.

Repeatable antenna measurements can be made provided the ferrite is degaussed or the current is applied in one direction only after degaussing. Degaussing the antenna establishes a baseline reference for the Faraday rotators causing them to provide the same E-field rotation for a given current value. Depending on the application, degaussing the antenna may or may not be necessary. The two most notable effects of the antenna, if the unit is not degaussed, are the variation of the amount of rotation with coil current and degradation of the cross-polarization level on the order of 5 to 10 dB

Early in the design of the antenna, several references [1-7] were searched for information relevant to this type of application. Although Faraday rotation has been well known for many years, most of its application has been in isolators, circulators, gyrators, or other similar components. No published literature was found on the use of electronically controlled Faraday rotation to produce a variable polarization antenna.

## EXPERIMENTAL MEASUREMENTS

An automated data acquisition system was designed and built to aid in the analysis of the antenna' s characteristics. The data acquisition system as shown in Figure 2 is comprised of a Macintosh computer using an IEEE 488 bus, a TSA microprocessor controller, a motorized rotating standard gain horn receive antenna with a rotary joint and resolver, a network analyzer, a generator and associated microwave components and adapters. The computer uses programs written in Basic to receive data from the network analyzer over the IEEE 488 bus and issue commands through its serial port to the TSA controller. The controller in turn receives these commands and produces coil currents via its digital to analog converter The software in the controller produces the degaussing square wave as well as the DC coil currents. The motorized horn antenna, the resolver and the controller software form a closed loop system to accurately position the horn at any angle

The computer coordinates the data acquisition process by applying currents, rotating the horn antenna and reading the analyzer screen at the appropriate times while storing data into files for later evaluation. Analyzing the antenna's performance required varying the parameters of frequency, angular position of the horn, and coil current. This acquisition system made it possible to collect and store the large amounts of data necessary for the analysis.

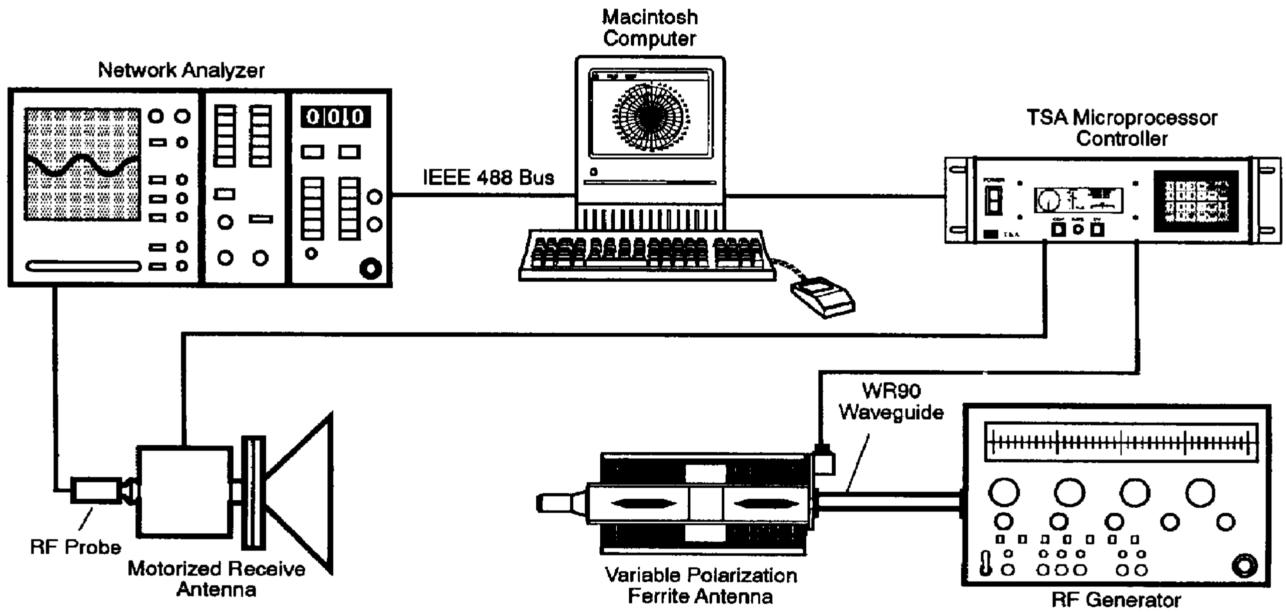



Figure 2. Automated Data Acquisition System

Current versus rotation data was taken on the Faraday rotators at several discrete frequency points over the frequency range of 9.0 to 11.4 GHz. Figures 3a to 3d show the amount of E-field rotation versus coil current at 9.0, 9.75, 10.5, and 11.4 GHz. For a given current, the amount of rotation increases as frequency increases. For example, at 9.0 GHz a current of 100 mA produces 20° of rotation and at 11.4 GHz the same current of 100 mA produces 60° of rotation. At the lower frequency of 9.0 GHz, more current is required to get the same amount of rotation as compared to the higher frequencies. The current versus rotation plot is linear over a certain region and then saturation of the ferrite occurs and the plot becomes nonlinear. At 9.0 GHz, there is constant rotation until approximately 50°, then between 50° and 65° the rotation versus current becomes nonlinear. After saturation of the ferrite, increasing the coil current produces no additional rotation.

The data of Figures 4 and 5 were obtained by applying fixed currents to the Faraday rotator coils and then rotating the receive horn antenna 360° about its axis, while simultaneously recording the resolver output angle and the network analyzer display. Figure 4a shows the ferrite antenna linearly polarized in the horizontal plane with both coil currents set to zero. The co-polarization angles are at 90° and 270° while the cross-polarization angles are at 0° and 180°. The cross-polarization level is a nominal -35 dB. Figure 4b shows a case where the ferrite antenna is circularly polarized with an axial ratio of 1.4 dB. The input coil current is 125 mA and the output coil current is 0 mA. Notice that 125 mA on Figure 3b for 9.75 GHz corresponds to approximately +45° of rotation which correctly orients the electromagnetic wave with respect to the quarter-wavelength phase shifter to produce circular polarization.

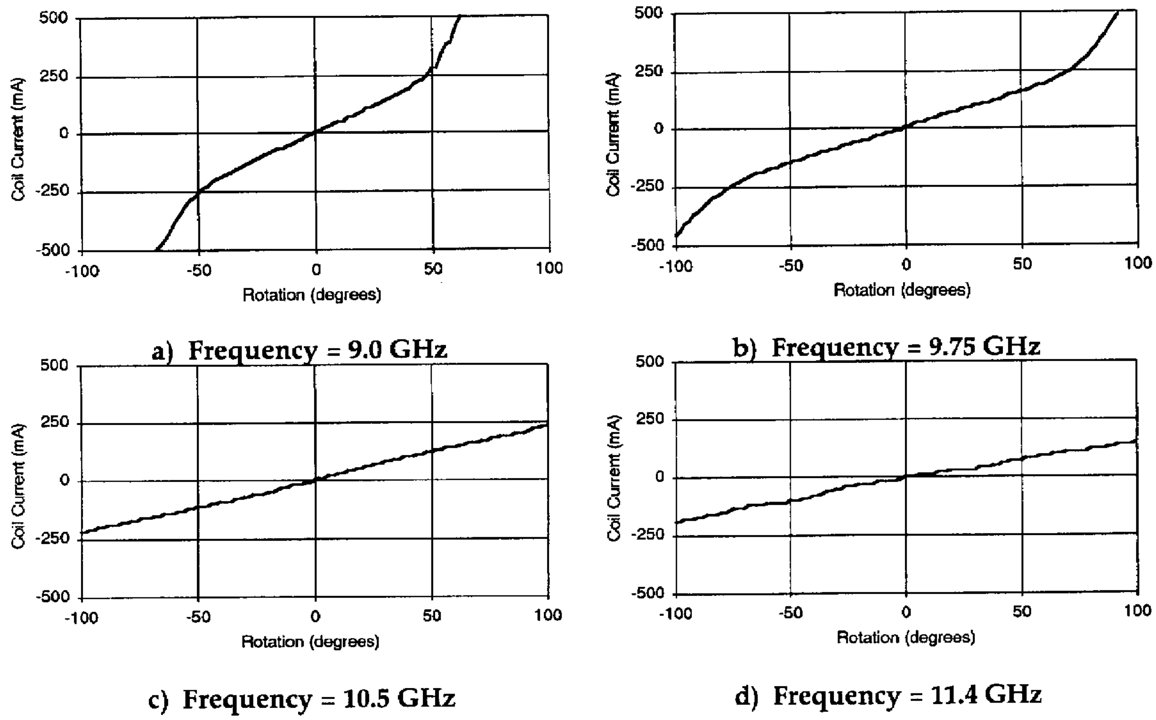
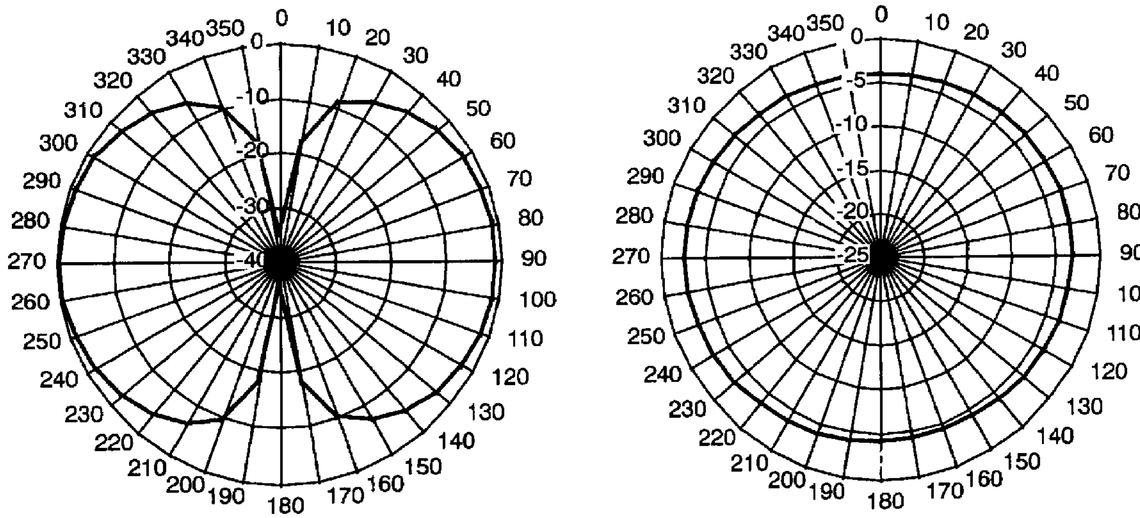



Figure 3. Measured E-Field Rotation vs. Coil Current

Figure 5a shows the ferrite antenna producing elliptical polarization with a -45° tilt angle with respect to 0°. The input coil current is 60 mA while the output coil current is 140 ma. Figure 5b depicts how changing the output coil current changes the tilt angle of the ellipse. The output coil current is changed from +140 mA to -140 mA and the orientation of the major axis changes from -45° to +45°.

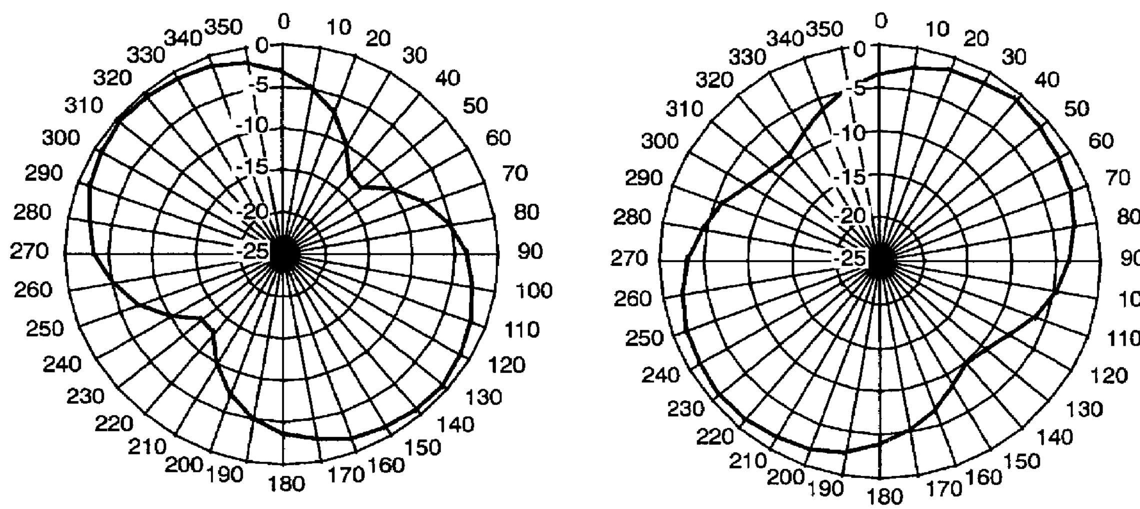
The return loss is ≥9.5 dB over the full X-band frequency range of 8.0 to 12.4 GHz. This correlates to a VSWR ≤2.0:1. The radiation patterns at 9.75 GHz were measured and have 3 dB and 10 dB beamwidths of 52° and 80°, respectively for E-plane, and 54° and 87°, respectively for H-plane. The aperture of the antenna could be modified to accommodate any realistic beamwidth requirement.




**a) 9.75 GHz, Input Coil Current = 0 mA, Linear Polarization**

**b) 9.75 GHz, Input Coil Current = 125 mA, Circular Polarization**

Figure 4. Relative Power (dB) vs. Angle (deg)




**a) 9.75 GHz, Input Coil = 60 mA, Output Coil = 140 mA, Major Axis at -45°**

**b) 9.75 GHz, Input Coil = 60 mA, Output Coil = -140 mA, Major Axis at +45°**

Figure 5. Elliptical Polarization

## CONCLUSION

A variable polarization ferrite antenna has been designed, built and its characteristics examined. The antenna has the ability to produce linear , circular or elliptical polarization of any orientation. The input Faraday rotator coil is responsible for producing the type of polarization and the output Faraday rotator coil is responsible for the orientation of the linear polarization or tilt angle of the elliptical polarization.

The ferrite antenna can switch polarizations instantly through electronic control, has no moving parts, and is a small, compact unit.

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