A DUAL MODE VARIBLE POLARIZATION PHASE SHIFTER

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ABSTRACT

A new type of the DMVPPS is introduced in this paper in general term. The features of the conventional DMPS is operated only linear polarised wave, while DMVPPS consists of a NRCP, a FR and a VP. A linear polarized wave entering the device is converted to vertical horizontal position and negative circular polarization or arbitrary polarized wave in modern phased array radar of the techniques are given, it is reciprocal operated. Simple microwave structure, lower instertion loss, smaller size and less weight. Its behaviour can be compared with the conventional phase shifter.

INTRODUCTION

In order to study multiple target characteristics and identification and to adapt the requirements of space surveillance, this new design of phased array radar with changeable polarization have been developed during the past decades. Such as its antenna may use the dual mode varible polarization phase shifter (DMVPPS) is shown unitof array in Fig.1, which consists of a non-reciprocal circular polarizer (NRCP), a Faraday rotator (FR) and a varible polarizer (VP). The control winding for the FR and VP are excited by a electronic driver. A linear polarized wave entering the device is converted into a circular polarized wave by tha NRCP, the FR causes the wave to phase shift as it propagates through this section of the device. The basic funcation of VP is always designed to work on changeable polarization, usually four kinds of polarization -- left and right circular, linear horizontal and vertical are controlled in transmitting and receiving polarized wave. Some advantages of the device are reciprocal operation, simple microwave structure (the basic microwave waveguide can be all one piece), lower insertion loss, smaller size and less weight.

BASIC PRINCEPLES

The basic structure is used a completely to fill up a geometry in which the surface of the ferrite of round rod is metallized to form a circular waveguide. The amount of the DMVPPS available from the varible-fixed axially magnetized and transverse magntized section respectively depends of the saturation moment, remanence ratio, operating frequency and cross-sectional dimension of the circular waveguide, at present with a view to by using a relationship of polarization transform between the input and output can be easily discribed by a polarization transform matrix (PTM) as follows:

A. Transmitting Polarized Wave of the Device

If the input linearly polarized wave to NRCP section is expressed in Fig.2 (1--2) output wave is given by

$$\begin{bmatrix} E_x \\ E_y \end{bmatrix}_{out} = \begin{bmatrix} T \end{bmatrix}_{PTM} \cdot \begin{bmatrix} 0 \\ 1 \end{bmatrix}_{in} = \frac{j\exp(-j\Phi)}{\sqrt{2}} \begin{bmatrix} 1 \\ -j \end{bmatrix} \quad (1)$$

where (1) as lift circular polarized wave.

B. Receiving Polarized Wave of the Device

Similar above procedure (2--1).

$$\begin{bmatrix} E_x \\ E_y \end{bmatrix}_{out} = \frac{1}{\sqrt{2}} \begin{bmatrix} T \end{bmatrix}_{PTM} \cdot \begin{bmatrix} 1 \\ -j \end{bmatrix}_{in} = -j\exp(j\phi) \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad (2)$$

According to (2), the output of the device at left end is appeared always in the vertical linearly polarized wave.

C. Varible Polarized Wave of the Device

Fig.2 shows (2--3) VPW for a CP input to which, while various polarization output can be obtained to form varible polarizer only by properly magnetic field control, then its output as follows:

$$\begin{bmatrix} E_x \\ E_y \end{bmatrix}_{out} = \begin{bmatrix} \cos\theta_N & j\sin\theta_N \\ j\sin\theta_N & \cos\theta_N \end{bmatrix}_{PTM} \cdot \begin{bmatrix} E_x \\ E_y \end{bmatrix}_{in} \quad (3)$$

According to (3), if θ_N=0°, ±45°, 90° or arbitrary angle, as a consequence formula (3) can corresponded at output of multiple polarized wave.

DESIGN AND EXPERIMENTAL RESULTS

Design of the Phase Shifter Section

When the circularly polarized wave pass through the phase shifter section, the propagation constants depend on the waveguide structure and material parameters. The phase shifter section is made with the film-plated ferrite circular bar. It is combined with the ferrite magnet yoke which is used to keep the ferrite in remanence. The phase shifters are operating in latching mode. If the ferrite prototype is partly magnetized, accroding to the experiment results of Green, It's tensor element is

$$\mu = u_f + (1 - u_f)\left(\frac{Mr}{Ms}\right) \quad (4)$$

where u_f is the initial permeability, it is given by

$$\mu_f = \frac{1}{3} + \frac{2}{3}\sqrt{1-\left(\frac{\omega_m}{\omega}\right)^2} \quad (5)$$

$$K = \frac{Mr}{Ms} \cdot \frac{\omega_m}{\omega} = R_r \cdot P \quad (6)$$

where R_r is the remanence ratio, P is the normalized magnetic moment. When the operating mode of metallized ferrite circular waveguide from $-M_r$ to $+M_r$ in the sectional circular waveguide filled with ferrite, the calculated formula of Faraday roating phase shifter section resulted from the coupling wave theory is given by

$$\Delta\beta = 2\beta_{11} \frac{K}{\mu} \cdot \frac{1}{1.84^2-1} \quad (7)$$

$$\beta_{11} = \frac{2\pi}{\lambda_0}\sqrt{\varepsilon\mu - \left(\frac{\lambda_0}{3.41R}\right)^2} \quad (8)$$

When the ferrite circular bar's radius R=0.502cm, εr=14, λ_0=5.5cm, P=0.6, R_r=0.8-0.9, for (4), (5) and (6) substituting in (7) and (8) gives $\Delta\Phi$=49°/cm so that determines the length of phase shifter section. For the maximum differental phase shift equal 420°, according to (7) the length of phase shifter section is 8.5cm. It's experiment value is 8.7cm. The calculated value basically correspond to the experiment value.

The Calculations of Fixed Circularly Polarizer and Latching Yoke VP

According to the structure in the Fig.2, we choose each section of ferrite circular waveguide of both which are transverse magnetized in the direction. The principles both two devices are the same, one is fixed and other is latching yoke variable-polarized which can make the polarization switching speed to microsecond order. The metallized ferrite circular bar is talen for dual-mode waveguide which surround by toroid closed touch with the ferrite bar. The air-gap between the circular bar and the toroid is reduced to minimizing for operating in latching mode. The four little circular holes in the toroid are used for the exciting wires. For adjusting the currents in exciting wires and can obtained the differental remanence status and the differental polarization switching can be controlled.

According to wave mode between the add and even mode in the cylinder prototype, the differental phase shift is given by

$$\Delta\beta = 2.11 \frac{K}{\mu a} \quad (9)$$

where a is the waveguide radius. If we consider the influence of prototype shape's demagnetizing factor and nonsaturation factor, K/μ is given follows

$$\frac{K}{\mu} = \frac{M}{Ms} \frac{P}{[1-P^2S(1+S)]} \tag{10}$$

$$S = \frac{\omega r}{\omega m}\left(\frac{M}{Ms} - \frac{1}{2}\right) \tag{11}$$

If using M/Ms=0.75, gives S=0.433. Substituting P=0.6 in (10) and (9) , then the lengths of circularly polarizer and VP equal separately 0.7cm and 1.4cm. Their experiment values are 0.85cm and 1.6cm separately. We obtain the differental phase shift 0°, ±90°, 180°, i.e. vertically polarized wave, left-handed circularly polarized wave,right-handed circularly polarized wave, horizontally polarized wave or arbitrary polarized wave. The calculated values basically correspond to the polarization mode which is obtained by the experiment.

Experimental Results

In the structure as shown in Fig.2, the size of metallized ferrite circular bar is 11cm x 1.04cm, It is connected with the standard square-waveguide (3.2 x 3.2 cm^2), it's air-gap are realized by the transition of RF ceramic (εr=6.6). The basic features of DMVPPS is as follows:

frequency	C-band,bandwidth 7%
peak power	4kW
average power	40W
VSWR	<1.25
insertion loss	<1.1dB
switching time	<30us
differental phase shift	0° — 420°
VP differental phase shift	0°,±90°,180°
VP switching time	<10us
DMVPPS length	11cm
weight	150g

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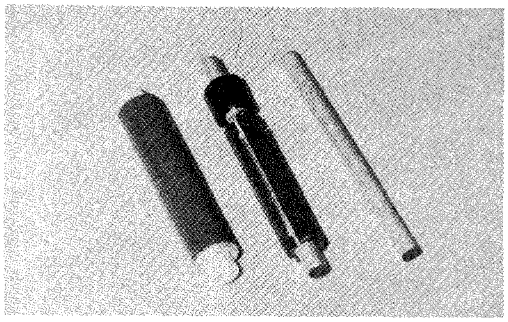

Fig.1 DMVPPS element

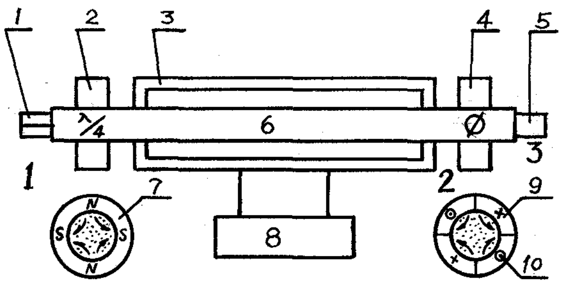

Fig.2 Sketch of DMVPPS

1. polarized filter	2. fixed NRCP
3. latching yoke	4. VP
5. transverter	6. metallized waveguide
7. permanence	8. driver
9. latching yoke	10.driving pulse