Abstract

This paper presents the results of calculating and modeling of phase shift in passing through the television signal phase shifter that contains incorporates MEMS-driven sections, which carry change direction of polarization of the signal. According to the simulation results, which are presented in the paper can draw conclusions about the development of a design with optimum geometrical parameters, the values were obtained from the results of the implementation of simulation optimization.

Introduction

Shifter is an integral part of many electronic systems. The development of these elements become especially important due to the structure of modern trends transmitter-receiver channels of communication systems for multi-channel schemes. Management phase and amplitude in each channel can implement advanced signal processing techniques and, by doing so, significantly improve receiver sensitivity and lower power requirements for transmitters.

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Microwave phase shifter - the range is an important component of an important component of radio-technical systems. They are used in radar equipment, ligament and measurement technology, the phase modulation signal. Also, and this is extremely important, they are part of monopulse systems and phased antenna arrays (PAA), which control the phase of the radiating elements, providing spatial scanning beam antenna.

Depending on the nature of the management of differentiated smooth phase (analog) and discrete (stepped) phase shifter (PS). Analog phase shifters provide smooth and discrete - speed phase change (usually in increments $\frac{360^\circ}{n}$, $n$ – number of digits phase shifters). In the PAA commonly used electromechanical or semiconductor phase shifters, although manifested considerable interest and a new type of PI implemented based on MEMS.

In recent years, the field in the field of microwave phase shifters made significant progress. Firstly, this is due to the use of monolithic circuits that can not only dramatically minimize the size, but also to create a fundamentally new schemes (eg, vector) and PS design with precision parameters in ultra-wide band of operating frequencies.

Second, researchers proposed new circuit and design of phase shifters that have the characteristics that are inaccessible using circuitry previous years. Lastly, there proprietorship based on MEMS. In fact, the parameters of phase shifters that are reported in the current prospectus and on the web, so high that professionals unfamiliar with the current state of affairs in this area can cause some distrust.

The main parameters of phase shifters (except phase characteristics) are: the level of losses being made, bandwidth, dependent damping, introduced from the phase state (parasitic amplitude modulation), the maximum transmitted power, weight, size, switching time.

Polarization of an electromagnetic wave

Radio or television program is the distribution of electromagnetic waves having two transverse (perpendicular) components: the electric field E and the magnetic field H. These fields form a plane situated at right angles to the direction of wave propagation (Fig.1). E-field orientation in relation to the earth’s surface is called polarized electromagnetic wave [1].
If the E-field vertical, the transmitted signal is called vertically polarized, if the E-field is horizontal, then the transmitted signal called horizontally polarized. If the E-field vector rotates a transmitted signal has a circular polarization.

With satellite television broadcasting using only using only vertical and horizontal polarization. This method allows the use of dual polarization radiation of one frequency in two different channels: one vertical polarization, the other horizontal polarization. However, the frequency of overlap can cause crosstalk, and therefore the transfer is usually not used. In practice the use frequency distribution without overlapping and adjacent channels to minimize intermodulation between the transmitted signals with opposite polarization.

Speed of propagation may depend on its polarization. Two wave linearly polarized at right angles to each other do not interfere.

Often this phenomenon is used to create different optical effects, where polarization is used to separate the images you right and left eye.

Circular polarization is applied to the antenna space lines, because reception is not important provision of the plane of polarization of the transmitting and receiving antennas. That is, the rotation of the spacecraft will not affect the possibility of communication with him. In a land line using linear polarization antenna - you can always choose in advance - horizontally or vertically placed plane of polarization antennas. Circumferential polarization antenna to perform more complex than linear polarization antenna.

Generally, circular polarization - something theoretical. In practice talking about elliptical polarization antenna - with the left or right direction of rotation.

Principle of polarization converter

Currents in metallic waveguides occur in different parts in different ways. For vertical walls are perpendicular to flow up and down the walls. In the horizontal walls of the flow pattern is more complex. Currents of vertical sections of direction to the middle to the middle horizontal wall in the longitudinal direction of the currents continue to move in currents that flow in the capacitors. There’s a current flows from one wall to the other horizontal. Just in these areas should be managed to locate items that affect the flow of current conditions, and consequently the conditions of wave propagation along the waveguide. Detailed dissemination-ing currents shown in Fig.2.

Managed type of polarization converter comprises two orthogonal symmetric periodic structures that incorporate isolated from the main part of the elements. Electrical connection elements isolated from the walls of the waveguide by using microelectromechanical structures (MEMS), which is implemented in the form of electromagnetic controlled capacitor having a disc-shaped electrode coated with an insulator with a high dielectric constant, and the second - a moving flat spring with mahninton'yakoho material.

When snug fit electrode to diethyl lektrychnoho cover a large capacitance. In the presence of the control magnetic field generated by an electromagnet, moving away from the electrode dielectric cover a considerable distance. The effective dielectric constant of the capacitor gap in this case is much smaller. The distance between the plates is much larger, which leads to low terminal capacitance.

Thus we have two values of capacitance between the isolated element and the housing waveguide, which leads to two values, velocity of wave propagation in the waveguide with the periodic structure.

If both pairs of periodic structures are in the same position, the orthogonal wave propagating in the waveguide with the same speed, ie in phase and does not affect the type of polarization of the wave coming.
Calculation of the commutation relation

Equivalent circuit (Fig.3) can be represented as a set of capacitive and inductive elements. They differ in that the rods have different length and diameter, and hence the equivalent inductance element and the distance of the rod, the body electrodynamic structure that defines the container.

\[ L = \sum_{i=1}^{n} L_i + \sum_{i=1}^{m} M_{iki}, \quad i = k \]

\[ M = \sum_{i=1}^{n} M_{iki} \]

The mutual inductance of linear conductors can be taken as mutual inductance \( \overline{M_{iki}} \) axial filaments \( \dot{i}_1 \) and \( \dot{i}_2 \) these wires

\[ \overline{M_{iki}} = \overline{M_{iki}} = \frac{\mu_0}{4\pi} \int_{i_1}^{i_2} \frac{dl_1 dl_2 \cos \theta}{r}. \]

Net inductance of the wire line can be represented as

\[ L = \overline{L} - G + A - Q, \]

where \( \overline{L} \) – value that depends on the shape and size of the wire axis and does not depend on the shape and size of the cross-sectional;

\[ G, A, Q \] – quantities that depend only on the shape and size of the cross section and the nature of the distribution of power in section, with a high degree of accuracy A and Q tend to zero, ie

\[ L \approx \overline{L} - G. \]

Inductance straight wire

\[ L = \frac{\mu_0}{2\pi} \left( \frac{\ln 2l - 1 - \frac{1}{2} \int \ln \frac{d\dot{s}^l d\dot{s}^l}{d\dot{s}^l}}{2} \right) \]

As the third part is the logarithm of the geometric mean distance (DMD) \( g \) S cross-sectional area of the wire itself, we can write

\[ L = \frac{\mu_0}{2\pi} \left( \frac{\ln \frac{2l}{g} - 1}{2} \right). \]

Net inductance of the wire with a constant cross-section with a uniform distribution of current on the mutual inductance section is relevant equidistant strands distant from each other at a distance \( g \), equal to the average geometric distance cross-sectional area of the wire itself. This principle is the geometric mean of distances.

The general formula of inductance

\[ \dot{L} = \frac{\mu_0}{2\pi} \left( \ln \frac{l + \sqrt{l^2 + g^2} - \sqrt{l^2 + g^2} + g}{g} \right). \]

Principle gives the exact result for two infinitely long straight wire of constant cross section. In other cases, the smaller the error, the smaller the linear dimension of the cross-sectional comparison with its length.

Inductance wire of rectangular cross section is obtained substituting \( g \) for DIS square rectangle with sides \( b \) and \( c \)

\[ \ln g = \frac{1}{2} \ln(b^2 + c^2) - \frac{1}{12} \frac{b^2}{c^2} \ln \left( 1 + \frac{c^2}{b^2} \right) - \frac{1}{12} \frac{c^2}{b^2} \ln \left( 1 + \frac{b^2}{c^2} \right) + \frac{1}{2} \ln \left( 1 + \frac{b^2}{c^2} \right) + \frac{1}{2} \ln \left( 1 + \frac{c^2}{b^2} \right). \]

Often used approximate formula for \( g \)

\[ g = 0.222 b (b + c) \ln g = \ln(b + c) - 1.5. \]

For rectangular wire

\[ L = \frac{\mu_0}{2\pi} \left( 1 + \frac{QR}{\alpha + \varphi} - 0.5 \right). \]
The main geometrical parameters of the membrane

The resulting inductance dial position of the membrane is zero.

Switching elements connected by two flexible elements because their total inductance is twice smaller.

Inductance other provision of the elastic membrane is zero.

Capacitive switching circuit shown in Fig.5. Calculation of volume occurs as the calculation of capacitance plate capacitor consisting of two parallel metal plates each plane S which are located at a distance d from each other [2].

Switching position of the same membrane. When you squeeze the stress position it can be argued that to achieve the desired effect to uniformity of structure and uniform influence on the entire frequency range, which is a measure of graph shows that the signal is constant over the signal passed through it.

Simulation results polarization converter

For simulation it was chosen only part of the polarization converter Fig.6, since all device simulation is a very time consuming process, therefore, to obtain the necessary shift \(90^\circ\) having the results of one section, it is possible to develop a device with the number of sections.

After transmission of television signals via a system of commuting polarizer C ranges, well, both with vertical and horizontal polarization was received significant change in the magnetic field switching and its absence (Fig.7 and Fig.8).

From these diagrams, which clearly shows that the resulting signal passing through such a MEMS structure, made significant changes in the phase shift when switching (change of position) Noah elastic membrane. When you squeeze the stress position zhenist magnetic field is much larger than the switching position of the same membrane.

The change in phase shift can be seen in the chart gap passage of two signals (Fig.9). From these results it can be argued that to achieve the desired effect to position 5 pair of MEMS structures. Also from this graph shows that the signal is constant over the entire frequency range, which is a measure of uniformity of structure and uniform influence on the signal passed through it.
Fig.9. The phase delay between vertically and horizontally polarized signal

As a result of the optimization was you-values for significant impact on the phase delay provides: height cylinders (pins), the comb structure. By increasing the height of pins is increased degrees Celsius phase shift. The results of this dependence is shown in Fig.10.

![Graph showing phase delay vs. pin height](image)

Fig.10. Dependence of the phase shift by increasing the height of pins

Consistency of system

Another important parameter in the converted voryuvachah polarization is consistent throughout the range of frequencies. In result of the optimization of geometrical parameters appliance, it was found that the coherence of the whole system is affected by distance between the switching elements. This dependence is shown in Fig.11.

At a distance of 20 mm between sections MEMS ultrasonic hodhenist is quite adequate, it can be seen in Fig.12.

![Graph showing consistency vs. distance](image)

Fig.11. Consistency structure with two sections

![Graph showing adequate coordination of two polarized signals](image)

Fig.12. Adequate coordination of the two polarized signals

Conclusions

The results of experiments and calculations the following data were obtained:
- achieved total phase shift of 90 degrees;
- coordination structure not exceeding 0,005 degrees;
- design is optimal and does not exceed the allowable size;
- achieved high performance and durability of the device thanks to the presence in it of MEMS.

Thus in spite of the progress made in creating microwave phase shifters, outlines directions for their further improvement in order to minimize the size and attenuation, introduced, to improve the accuracy of phase states and setting performance, extend the frequency range and, finally, implementation of adaptive control systems precision settings phase states.

References


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