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DESIGN AND PERFORMANCE OF A K_U-BAND ROTMAN LENS BEAMFORMING NETWORK FOR SATELLITE SYSTEMS

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Abstract—This paper presents the novel theoretical design, CAD modeling, and performance analysis of a compact and reliable microwave beamforming network (MBFN) which has been developed based on the RF Rotman lens switched-beam steered array for operation in K_u frequency band. The objective of this investigation is to develop a passive beam steering microwave network device intended for the potential suitable use in satellite communications beam scanning electronically scanned arrays. A thorough K_u-band satellite microwave network system has been theoretically designed and simulated along with the analysis of its output RF characteristics. The antenna array feeding network is capable of multi-beams generation and wide-band operation in terms of the true-time-delay (TDD) and low dispersive properties in order to allow simultaneous operation of multiple RF beams. The Rotman lens demonstrates the potential appropriateness in order to develop a high-performance and well-established design for advanced satellite microwave systems, services, and devices.

1. INTRODUCTION

Employing innovative microwave switched-beam smart antenna systems for operative satellite services and terminals at K_u-band can greatly enhance the performance of these systems by providing better RF link quality and maintenance, and high immunity to interference. The RF beam switching mechanism introduced with these systems suits well to the satellite systems transceiver need by fulfilling the requirements of improving the satellite coverage range, high data-rate, and QoS. Generating multiple RF beams using an array network

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along with having wide-bandwidth and RF beam steering capability, are of crucial importance for satellite systems. For this purpose, microwave beamforming networks (MBFNs) have been introduced to have control over the amplitude and phase at each element of the array. The Rotman [1–4] passive lens-based RF beamforming network forms an important class of these systems and can be potentially used in advanced satellite communication systems. Satellite systems can utilize the Rotman lens MBFN in order to achieve high-performance features such as high-directivity, RF steering coverage, and frequency-invariant RF beam directions. The microwave network can increase the capacity and provide higher SIR, consequently enhancing the overall satellite array performance. The Rotman lens MBFN is practically convenient and electrically efficient microwave device for generation and focus of multiple narrow RF beams toward specified angular directions for digital satellite transceiver systems such as DVB.

2. SATELLITE ROTMAN LENS MICROWAVE BEAMFORMING NETWORK: DESIGN AND ANALYSIS

The lens-based Rotman-type is an attractive beamforming network due to its low cost and mass-producibility, reliability, compactness, design flexibility, and wide-angle radio scanning capabilities. This RF device uses the free-space wavelength of a signal injected into a geometrically configured waveguide to passively shift the phase of inputs into a linear antenna array to scan a beam in the desired RF pattern. It has a carefully chosen shape and appropriate length transmission lines (TLs) in order to produce a wave-front across the output that is phased by the time-delay in the microwave signal transmission. The RF lens achieves beam scanning using equivalent time-delays that are created by the different path lengths to the radiating elements. The lengths depend on the relative position between the beam port and the array ports on the structure. As long as the path lengths exhibit constant time-delay behavior over the system bandwidth, the lens is insensitive to the beam squint problems exhibited by constant phase MBFNs [5]. The lens predicts the primary amplitude distribution across the array port; amplitude distribution depends upon the gain of array contour of the lens. The modeling is based on placing physical ports of lens input on the microwave theoretical phase centers. These phase center positions are computed based on the geometrical optics (GO) under the assumptions of cylindrical waves and true-time-delay (TTD) [6]. The phase shifts increase from one element to the next, and result in a microwave radiation pattern with a single beam pointing into a certain direction on the RF lens axis [7].

Each input port will produce a distinct beam that is shifted in angle at the output. The design of the lens is controlled by a series of accurate equations that set the focal points and array positions. The inputs, during the design of the system, include the desired number of RF beams and array elements, and the spacing of the elements [8, 9]. As the RF lens is a TDD device, it produces beam steering independent of RF frequency and is therefore capable of wide-band operation. The cost of a lens implemented on microwave material is primarily driven by the cost of the material itself and the price of photo etching [10]. A Rotman lens has M beam ports and N array ports, and it has the capacity to form M discrete beams in different directions; and involves steering an off-axis incident plane wave directed onto the microwave array ports to angularly separated beam ports. When employed as a beamforming network and an individual RF beam port is excited, energy travels through the device to arrive at the RF array ports with linearly progressed phase shift.

Electromagnetic (EM) radiation energy then applied to the radiating elements attached to each lens array port will result in beamforming in a specified direction. In receive mode, a plane wave incident on the array ports with incident angle θ_m will be directed to the mth port subject to input of a linearly progressed phase at the RF array ports with a phase slope of $kd \sin\theta_m$ [11]. For the theoretical matrix modeling of the satellite Rotman lens the microwave beam ports and array ports are numbered from 1 to M and 1 to N respectively. It should be noted that the lens dummy ports are not taken into the matrix modeling since it is assumed that all these ports are perfectly matched to eliminate unwanted reflection. The field coefficients at the beam ports and array ports are also denoted by $B_1, \ldots, B_M$ and $A_1, \ldots, A_N$ respectively [12]. The transmission mode transfer matrix which describes the beam to array ports transformation can therefore be defined as the following RF transfer matrix Equation (1):

$$\begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_N \end{bmatrix} = \begin{bmatrix} S_{1,1} & \ldots & S_{1,M-1} & S_{1,M} \\ S_{2,1} & \cdots & S_{2,M-1} & S_{2,M} \\ \vdots & \ddots & \vdots & \\ S_{N,1} & \ldots & S_{N,M-1} & S_{N,M} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_M \end{bmatrix}. \tag{1}$$

where parameter $S_{n,m}$ defines phase delay between the mth beam port and nth array port; and can be approximated as (2):

$$S_{n,m} = e^{jk(L(m,n)+w_n)} \approx e^{jk(F_m+w_0-\eta_n \sin\alpha_m)}. \tag{2}$$

where k is the wave-number in the microwave lens region.

By substituting the Equation (2) into (1), the transfer matrix that models the lens beam port response can be created as (3):

$$\xrightarrow{yields}\ \mathbf{S}_{BtoA,aligned}$$

$$= e^{jkW_0}\begin{bmatrix} e^{-jk\eta_1\sin\alpha_1} & \cdots & e^{-jk\eta_1\sin\alpha_{M-1}} & e^{-jk\eta_1\sin\alpha_M} \\ e^{-jk\eta_2\sin\alpha_1} & \cdots & e^{-jk\eta_2\sin\alpha_{M-1}} & e^{-jk\eta_2\sin\alpha_M} \\ \vdots & \ddots & & \vdots \\ e^{-jk\eta_N\sin\alpha_1} & \cdots & e^{-jk\eta_N\sin\alpha_{M-1}} & e^{-jk\eta_N\sin\alpha_M} \end{bmatrix}$$

$$\times\begin{bmatrix} e^{-jk(F_1+V_1)} & & 0 & 0 \\ 0 & \cdots & e^{jk(F_m+V_m)} & 0 \\ \vdots & \ddots & \vdots & \\ 0 & \cdots & 0 & e^{jk(F_M+V_M)} \end{bmatrix}. \qquad (3)$$

where $\eta_n = [n - (N+1)/2] \times d$; V_m is an extra phase term applied to each RF beam port, and $e^{jk(V_M)}$ is an extra phase shift added to the mth RF beam port; and $[(n = 1, \dots, N), (m = 1, \dots, M)]$.

The transfer matrix has two parts: the common phase-delay shared by the array ports [i.e., $e^{jk(w_0+F_m)}$]; and the progressed phase through array port [i.e., $e^{jk(-\eta_n \sin\alpha_m)}$], which leads the RF beam in angle α_m, and contributes to the RF beamforming. The first matrix in the Equation (3) presents the MBF feature of the Rotman lens, and the second matrix (i.e., a diagonal matrix) shows the phase shift for each individual beam port excitation. Also, if the second matrix in (3) is constrained according to (4), it becomes an identity matrix; and the phase alignment requires the phase-delay path (i.e., $F_m + V_m$) to be maintained constant in order for the Rotman lens to

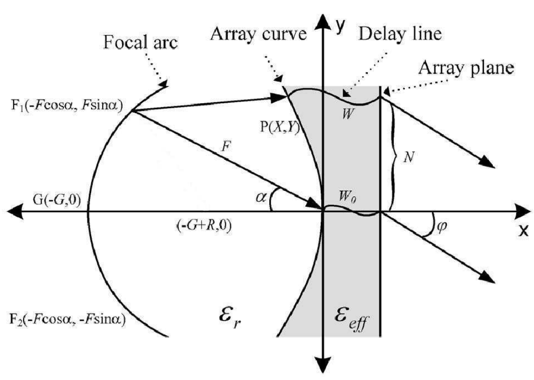

Figure 1. Microwave Rotman Lens geometry and design parameters [13].

retain the true-time-delay (TTD) characteristic of the device. This method is essentially required in the case of simultaneous multiple RF beam port excitation to obtain reconfigurable far-field microwave radiation properties for the satellite RF lens; otherwise V_1 to $V_m = 0$ (Figure 1) [12].

$$e^{jk(F_m+V_m)} = constant. \tag{4}$$

It is required that the intended lens form undistorted narrow patterns in the desired directions by producing a linear phase variation along the array aperture; therefore a set of lens design equations based on the GO are synthesized and employed. In the RF lens design, one focal point is located on the central axis and two other focal points namely F_1 and F_2 are symmetrically located on either side on feed contour. The off-axis focal points F_1 and F_2 are located on the focal arc. Inner contour and outer contour are connected by using TEM mode TL (i.e., W). Every receiving beam port that lies on the inner contour and has the coordinates (X, Y) is connected to corresponding array element by the TL. A ray originating from point F_1 on the feed contour reaches the wave-front through a general point $P(X, Y)$ on the lens inner contour TL, and then traces a straight line at an angle α and terminates perpendicular to the wave-front. All other rays from other feed points may reach their respective wave-front as well in order to produce required radiation pattern [7]. A beam port located at any of these three focal points results in a linear phase variation at the receiver ports, whereas beam ports at any other locations on the lens feed contour yield phase errors that cause defocusing of the produced radiation beam patterns. The RF lens design relations are given by the following equations:

$$\sqrt{\varepsilon_r}\overrightarrow{(F_1P)} + \sqrt{\varepsilon_{\mathit{eff}}}W + N\sin\alpha = \sqrt{\varepsilon_r}F + \sqrt{\varepsilon_{\mathit{eff}}}W_0 \tag{5}$$

$$\sqrt{\varepsilon_r}\overrightarrow{(F_2P)} + \sqrt{\varepsilon_{\mathit{eff}}}W - N\sin\alpha = \sqrt{\varepsilon_r}F + \sqrt{\varepsilon_{\mathit{eff}}}W_0 \tag{6}$$

$$\sqrt{\varepsilon_r}\overrightarrow{(F_0P)} + \sqrt{\varepsilon_{\mathit{eff}}}W = \sqrt{\varepsilon_r}G + \sqrt{\varepsilon_{\mathit{eff}}}W_0. \tag{7}$$

where ε_r and $\varepsilon_{\mathit{eff}}$ are the substrate dielectric constant and the TL effective dielectric constant respectively; F is the off-axis focal length; and N is the RF lens aperture.

$$\left(\overrightarrow{F_1P}\right)^2 = F^2 + X^2 + Y^2 + 2FX\cos\alpha - 2FY\sin\alpha \tag{8}$$

$$\left(\overrightarrow{F_2P}\right)^2 = F^2 + X^2 + Y^2 + 2FX\cos\alpha + 2FY\sin\alpha \tag{9}$$

$$\left(\overrightarrow{F_0P}\right)^2 = (X+G)^2 + Y^2. \tag{10}$$

The synthesis assumes several input parameters which are used to compute the RF array contour point as well as the line lengths. The parameters are element spacing (d), focal ratio (g), lens width (G), and scan angle (α) (Figure 1). The RF lens inner contour points and TL lengths are solved for using technique of path length comparison [1]. All the parameters and dimensions are normalized by F. These microwave BFN lens parameters are $d = N/F$, $w = (W - W_0)/F$, $x = X/F$, $y = Y/F$, $g = G/F$, and also $a_0 = \cos\alpha$, $b_0 = \sin\alpha$, $a_1 = \cos\alpha$, and $b_1 = \sin\alpha$. The lens design program solves for the length of the TDD line (w), which can be obtained from the following modified equations, and the array port coordinates from predetermined parameters and the satellite microwave lens structure dimensions [9, 13].

$$\xrightarrow{yields} aw^2 + bw + c = 0. \tag{11}$$

where

$$a = \frac{\varepsilon_{eff}}{\varepsilon_r}\left(1 - \frac{1}{\varepsilon_r}\left(\frac{b_1}{b_0}\right)^2 d^2 - \left(\frac{g-1}{g-a_0}\right)^2\right) \tag{12}$$

$$b = \sqrt{\frac{\varepsilon_{eff}}{\varepsilon_r}}\left(2g\left(\frac{g-1}{g-a_0}\right) - \frac{1}{\varepsilon_r}\frac{(g-1)}{(g-a_0)^2}b_1^2 d^2 + \frac{2}{\varepsilon_r}\left(\frac{b_1}{b_0}\right)^2 d^2 - 2g\right) \tag{13}$$

$$c = \frac{1}{\varepsilon_r}\left(\frac{g b_1^2 d^2}{(g-a_0)} - \frac{b_1^4 d^4}{4\varepsilon_r (g-a_0)^2} - \left(\frac{b_1}{b_0}\right)^2 d\right). \tag{14}$$

With the obtained value of TDD line, the microwave array port coordinate $P(x, y)$ can be determined from the equations as:

$$x^2 + y^2 + 2gx = \frac{\varepsilon_{eff}}{\varepsilon_r} w^2 - 2\frac{\sqrt{\varepsilon}_{eff}}{\sqrt{\varepsilon}_r} gw \tag{15}$$

$$y = \frac{b_1}{b_0} d\left(\frac{1}{\sqrt{\varepsilon}_r} - \frac{\sqrt{\varepsilon}_{eff}}{\varepsilon_r} w\right) \tag{16}$$

$$x = \frac{-1}{g-a_0}\left(\sqrt{\frac{\varepsilon_{eff}}{\varepsilon_r}} w(g-1) + \frac{b_1^2 d^2}{2\varepsilon_r}\right). \tag{17}$$

To calculate performance of the lens, the coupling between lens ports is approximated using aperture theory and a uniform distribution to the port aperture is implied. This RF port-to-port coupling determines how much EM energy is coupled from RF beam port to receiving array port; and is a function of the port sizes, port pointing directions, and port-to-port distance [6, 14]:

$$\mathbf{S}_{ij} = \sqrt{\frac{w_i w_j}{\lambda r}} \times \frac{\sin(x_i)}{x_i} \times \frac{\sin(x_j)}{x_j} e^{-j\left(kr+\frac{\pi}{4}\right)} \tag{18}$$

$$\text{where} \quad x_i = \frac{kw_i}{2} \sin\varphi_i. \tag{19}$$

These port radiation patterns are used to compute the direct path and reflected path propagation from port-to-port in order to improve the response of the outer beams [15, 16].

The satellite Rotman lens has employed the focal arc based on the elliptical curvature on the beam port side with major and minor radiuses r_a and r_b respectively, the coordinates (X_b, Y_b) of any designated beam port on the elliptical arc are determined as (20). The eccentricity parameter e of this focal arc is the crucial parameter affects the minimum phase error along the lens array ports [17], and is given as (21). The satellite lens could employ other focal arc configurations including: parabolic, hyperbolic, straight line, and circular; discussion of the individual design parameters for the mentioned geometries can be found in [18]. Each of these focal arc configurations has an impact on the RF power coupling from the feed contour to the array contour. The microwave lens shape determines the mutual coupling between ports and spillover losses (i.e., the coupling of energy from the RF beam ports to array ports due to sidewall reflection and vice versa). As the value of α increases, the array contour closes, its curvature increases, and the feed contour opens. As g increases, the array contour opens, the feed contour closes, and the gap between the feed contour and array contour also increases [18]. Equal heights of both contours are required in order to couple the maximum power from the feed contour to array elements.

$$\frac{(X_b + 1 - r_b)^2}{r_b^2} + \frac{Y_b^2}{r_a^2} = 1 \tag{20}$$

$$\xrightarrow{yields} e = \sqrt{\left[1 - \left(\frac{r_b}{r_a}\right)^2\right]}. \tag{21}$$

Thus, based on investigations of various lens performance parameters on the mentioned focal arc geometries, the RF lens with the elliptical geometry is more compact and yields fewer spillover losses. It has been observed the reflection coefficients and amplitude coupling obtained for all of the input ports are uniform and more uniformly coupled to the output ports; and the variation of the power reflected and distributed among ports from the outermost port to the inner port is comparatively less.

In the satellite lens, the offset RF beam port produces a path length difference and hence a phase gradient along the antenna array in order to perform steerable beamforming. There is also an additional lens parameter that gives the distance R from the lens center point to the focal point F_2 [17], and is given as (22):

$$R = \frac{(F\cos\alpha - G)^2 - (F\sin\alpha)^2}{2\,(G - F\cos\alpha)}. \tag{22}$$

For an active beam port at a focal point F_i, the amplitude a_n and the associated phase angle ϕ_n at the nth lens array port are determined for the RF array radiation pattern calculation using the Equations (23) and (24) respectively, and are given as:

$$P(\theta) = \left|\sum_{n=-m}^{+m} a_n e^{j(\phi_n+\varphi_n)}\right|^2 \tag{23}$$

$$\text{where} \quad \varphi_n = nk_0 d\sin\alpha - kW. \tag{24}$$

where $k_0 = 2\pi/\lambda$ is the wave-number for free space, $k = k_0/(\varepsilon_r)^{1/2}$ is the dielectric wave-number, W is the length of the TL (Figure 1) connecting the array port n on the inner contour of the RF lens to the corresponding array element n on the outer contour, and d is the uniform spacing between adjacent microwave antenna array elements. The parameters a_n, ϕ_n, and W are functions of the scan angle α_i corresponding to the lens focal point F_i [17]. The RF lens array ports are connected to the antenna array with constant time-delay, and as the direction of incoming RF signal and corresponding wave-front change, the maximum energy is routed to one of the beam ports. In the transmitting mode, the direction of radiation corresponds with the lens beam port fed to generate high-directivity RF beams for employment in orbit to provide bandwidth on demand anywhere within the satellite service area and maximize the overall RF system utilization. It is possible for the satellite phased array to adapt the pattern in real time to minimize the effects of the interfering external or multipath signals or to improve the signal-to-noise ratio (SNR). This is important for the satellite performance improvement.

3. SATELLITE ROTMAN LENS MICROWAVE BEAMFORMING NETWORK: SIMULATION AND DISCUSSION

According to the theoretical relations derived, the design, synthesis, simulation, and analysis of an 8×16 satellite Rotman lens beamforming network for operation in K_u-band has been carried out based on the

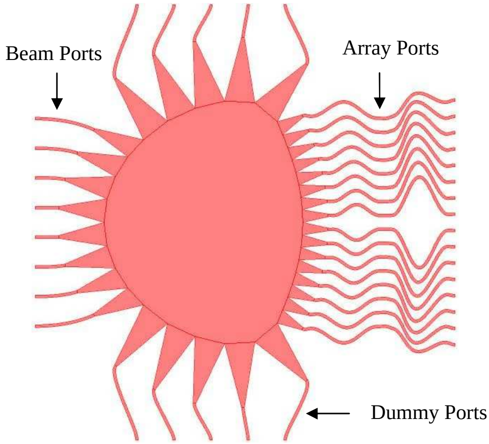

Figure 2. Layout of the proposed satellite 8×16 Rotman lens for the operating frequency of 14.5 GHz. The MBFN lens includes input beam ports; array-receiving ports; and dummy ports (each is terminated by a 50-Ω load).

GO real-time analysis. Figure 2 indicates the satellite microwave lens with an elliptical curvature on the beam port side that has been designed to have eight beam ports, sixteen array ports suitable for a sixteen-element antenna array; a beam scan angle of ± 30 at a center frequency of 14.5 GHz and bandwidth of 2.5 GHz; focal ratio (g) of 1.0845 (this small value gives a compact lens that has fewer spillover losses); an element spacing of 10.3 mm; and a compact size of 28.31 cm $\times$ 29.37 cm. The array ports have been spaced in such a way that elements of the array can be directly attached to the MBFN.

When designing the RF lens it has been important to ensure the element spacing is less than half a wavelength; otherwise the aliasing effect causes some side lobes which are larger in amplitude, and nearly identical copies of the main beam. The lens utilizes 16 array ports with an element spacing of about 0.5λ at 14.5 GHz to prevent grating lobes; Element spacing is therefore critical because it controls the appearance of grating lobes. For a maximum beam angle of θ_0, the maximum spacing between the array elements in a linear array should satisfy (25). Thus, the elements must be spaced one half-wavelength apart to prevent a second main beam when scanning close to endfire RF radiation ($\theta_0 = 0$ or π) or broadside radiation ($\theta_0 = \pi/2$) [19]. Antenna arrays present a built up of a number of individual RF radiators. Fields overlap and form a common antenna diagram through constructive interference, in order to be steered in a way to block the reception of RF signals coming from specified directions and combine the EM energy over the lens aperture.

$$d \leq \frac{\lambda}{1 + |\cos\theta_0|}. \tag{25}$$

If (25) is taken into consideration then the optimum spacing between two adjacent elements is $d \sim \lambda/2$; and the time-delay introduced for an array looking into the direction θ_s with an incident signal S_0 can be written as (26). Due to the equidistant spacing between elements, the phase shift of each RF element depends only on the incident angle θ_s (AOI) and its location.

$$S(\theta_s) = \sum_{n=-\frac{N-1}{2}}^{\frac{N-1}{2}} w_n(\theta_s) \cdot S_0. \tag{26}$$

where

$$\begin{aligned} \tau_n &= \frac{\lambda n}{2c} \sin(\theta_s) \\ \xrightarrow{yields} w_n &= \frac{1}{N} e^{jn\pi \sin(\theta_s)}. \end{aligned} \tag{27}$$

Geometry of routing is adjusted to ensure no overlapping, proper spacing between TLs, proper curvature, and maintaining overall lens physical length requirement. In order for the lens to obtain the desired RF performance, it is required to be tuned in terms of phase error or array factor (AF). The tuning procedure involves adjusting the lens focal ratio (g) that will minimize the error reported by the phase error. This parameter obtains the curvature of the lens, and if not adjusted accurately, will result in a messy beam production. Hence, the focal

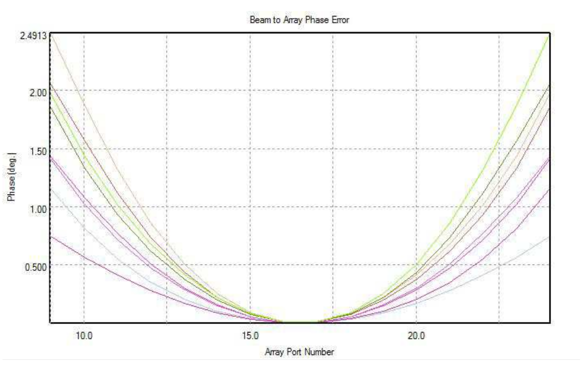

Figure 3. Satellite Rotman lens computed beam to array phase error.

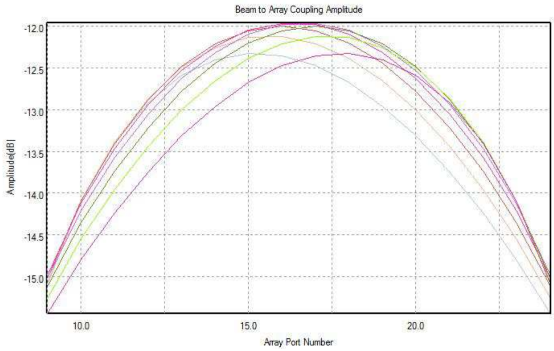

Figure 4. Satellite Rotman lens computed beam to array coupling amplitude.

ratio is adjusted to the value of 1.0845 in order to minimize the beam to array phase error that is distributed over the lens array ports in order to produce well-focused microwave scanning beams (Figure 3).

Figure 4 presents the K_u-band lens computed beam to array coupling amplitude distribution that has a roll-off of about 3 dB from the center of the array ports to the edges. Each plot shows the distribution across the output from one of the beam ports.

When a feed is placed at any one of the focal points on feed contour the corresponding wave-front has no phase error; when the feed is displaced from these focal points, the corresponding wave-front will have a phase error. However, in order for the RF lens to perform wide-angle beam scanning, the lens must be focused at all intermediate points along the focal arc. Therefore the difference in path lengths between a central ray through the RF lens origin and any other ray (Δl) can be derived as (28):

$$\Delta l = \frac{\Delta L}{F} = \sqrt{\varepsilon_r}\left(h^2 + x^2 + y^2 + 2h\cos\alpha - 2h\sin\alpha\right)^{\frac{1}{2}} + \sqrt{\varepsilon_r}w + d\sin\alpha - \sqrt{\varepsilon_r}h \tag{28}$$

where Δl is the normalized phase error; and h (i.e., H/F), is the normalized distance from a point on the focal arc to the origin.

The computed results for the 8 × 16 satellite Rotman lens RF steerable beamforming network indicate the expected outcomes by having the main lobe of the AF microwave radiation pattern more than 10 dB greater than the side lobes, and having a linear phase shift at each array port. It confirms how the amplitude distribution along the array contour is much more uniform with beam port pointing enabled (pointing the port toward the center of the opposite side of the lens). The progressive phase shift for the array ports exciting the beam ports ensures the generation of distinct beams and RF beam scanning concept verification; and is computed using the linear distance between the ports in the intended RF dielectric medium chosen. Figure 5 presents the overall RF lens computed AF radiation pattern. To scan the RF beam, the aperture distribution is activated and the microwave lens places two beams from port 1 and port 8 at ±30°. Figure 6 depicts the patterns of these two excited ports. Beam to array coupling amplitude (the array ports distribution from a given set of RF lens beams) has the expected value of −12.2 dB.

The satellite microwave beamforming network can be used

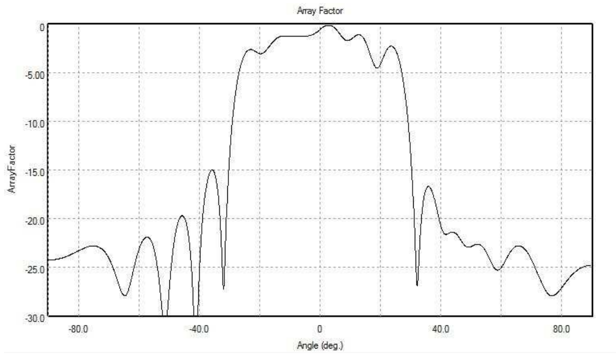

Figure 5. Satellite Rotman lens computed array factor radiation pattern.

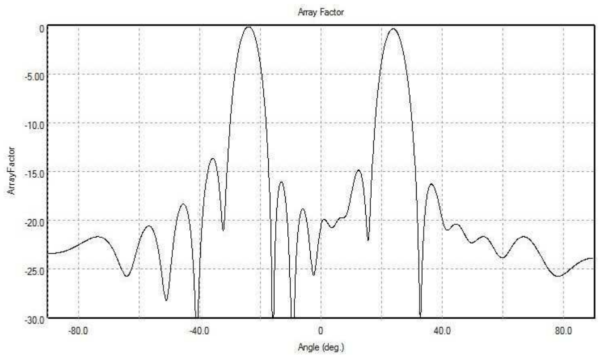

Figure 6. Satellite Rotman lens computed AF radiation pattern with beam port 1 and beam port 8 excited for aperture distribution beam scanning.

to improve SNR at the receiver, and to suppress RF co-channel interference (CCI) thus improving the SINR at the RF receiver. The generated microwave beam patterns are steerable in certain directions hence undesired paths can be suppressed potentially. The Rotman lens has generated high-gain beams over narrow scan ranges giving better beam control which results in reliable satellite microwave data link terminal services configurations. The microwave lens generated beam patterns have steered over the angles with the constant phase difference between adjacent radiating elements. Each exciting beam port generates a distinct AF pattern which then results in the propagation for the sixteen elements with well-defined RF beams formation. To generate a 3-D lens suitable for 2-D multi-beam satellite beam scanning, where there are hard conditions on the RF beam shapes, beam pointing locations, and beam switching in order to maintain the satellite links, combination of stacks of vertical and horizontal Rotman lenses can be potentially employed to produce row and column beamforming. The first set is stacked parallel to each other; the second orthogonal stacks of lenses are cascaded with the first stack so that the output ports of the first set excite the inputs to the second set to provide focusing in the elevation and azimuth planes respectively for satellite microwave scanning.

4. CONCLUSION AND RECOMMENDATION

In this contribution, a comprehensive and promising design for the satellite microwave Rotman lens-based switched-beam antenna feeding network has been carried out for operation in K_u-band. The microwave network has been accurately designed and analyzed; and can also be enhanced using finite-difference time-domain (FDTD) computational electromagnetics method. The system can further be integrated with amplifiers between the RF lens and the radiating elements as well as an RF MEMS switches for selection of the RF signal beam ports, and an A/D converter which samples the received signal and converts it to a digital signal and a DSP processor unit which then performs the FFT of the digital signal to separate out the amplitude and the phase parts; to form a satellite hybrid microwave-digital system. A dielectric inhomogeneous lens-based technology can also be employed to reconfigure RF beam shape in K_u-band.

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