A STUDY OF OMNIDIRECTIONAL ANTENNA FOR WIRELESS COMMUNICATIONS IN 18 GHZ BAND

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ABSTRACT

The construction of the microwave omnidirectional antenna with toroidal lens was proposed and formulas for calculating radiating characteristics were obtained. The optimal geometry of the antenna was formulated and prototype was designed and produced in 18 GHz band using polystyrene for lens and radome. The experimental study of the prototype was executed in frequency range 18÷19 GHz: input VSWR ≤ 2, antenna gain is equal 9.5 dBi with ripple ≤ 1.5 dB, beamwidth in vertical plane is about 10 deg., cross polarization level in principal planes ≤-25 dB. Calculated and measured data is in a good agreement.

DESIGN

An omnidirectional microwave antenna is widely used in wireless communication systems [1] and in this paper the data of such antenna development is presented. Antenna consists –fig.1 of antenna mount 1, axial waveguide to coaxial transition 2, biconical horn 3, toroidal lens 4, radome 5 and lightning 6. On the lateral surface of biconical horn of radius a_f and aperture size D_f the choke quarter-wave grooves 7 were produced to provide reduction of far-out side lobes on 7÷10 dB.

The expression for the power pattern of biconical horn in vertical E-plane was obtained [2] in approximation of aperture theory [3]

$$F_f^2(\theta_f) = F_0^2 \left| \frac{1+\cos\theta_f}{2} \cdot \int_{-1}^{1} d\xi_f \exp\left[-jka_f\sqrt{1+\xi_f^2 tg^2\alpha} + j\xi_f u_f\right] \right|^2 , \qquad (1)$$

where $tg\alpha = D_f/2a_f$, $u_f = (kD_f/2)\cdot\sin\theta_f$, $k = 2\pi/\lambda$, λ - wavelength, F_0^2-Const. The first summand in quantity in exponent describes the phase error in horn aperture $\Delta\varphi_{max} = ka_f\left(\sqrt{1+tg^2\alpha}-1\right)$, which expand the beamwidth and reduce the horn gain G_f. As it was shown [1], the optimal geometry of such horn (max G_f for min a_f) coincides to phase error $\Delta\varphi \cong \pi/2$ and is defined by expression

$$\frac{a_f}{\lambda} = \frac{D_f^2}{2\lambda^2} - \frac{1}{8}. \qquad (2)$$

To optimize the toroidal lens antenna parameters the following expression for the power pattern in vertical plane was obtained

$$F_V^2(\theta_a) = F_{V0}^2 \left| \int_{-1}^{1} d\xi_a M_1(\xi_a) M_2(\xi_a) M_3(\xi_a) F_f(\theta_f) \exp(j\xi_a u_a) \right|^2 , \qquad (3)$$

where

$$M_1(\xi_a) = \frac{1+\cos\theta_f}{2}; \qquad M_2(\xi_a) = \frac{\cos\theta_f + \cos(\theta-\theta_f)}{2};$$

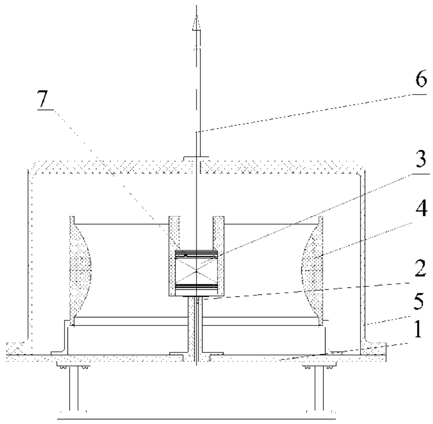

Fig.1 Scheme of the toroidal omnidirectional antenna

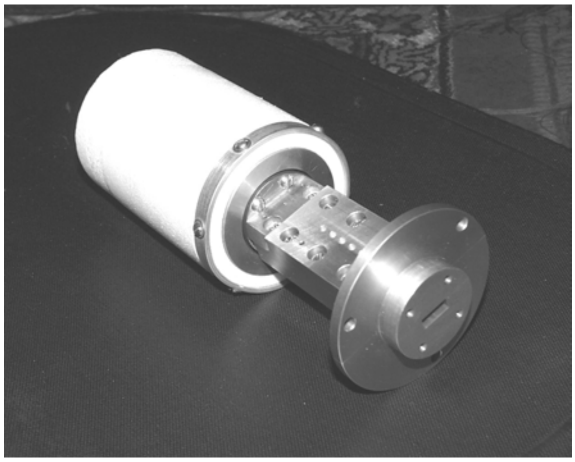

Fig. 2 Photo of the antenna feed

$$M_3(\xi_a) = \frac{n\cos\theta_f - 1}{\sqrt{(n-1)(n-\cos\theta_f)}}; \quad \cos\theta_f = \frac{1 - tg^2\frac{\theta_f}{2}}{1 + tg^2\frac{\theta_f}{2} 1};$$

$$\sin\theta_f = \frac{2tg\frac{\theta_f}{2}}{1 + tg^2\frac{\theta_f}{2}}; \qquad u_a = \frac{kD_a}{2}\sin\theta_a;$$

$$tg\frac{\theta_f}{2} = \frac{2F}{\xi_a D_a}\cdot\frac{n-1}{n+1}\left[\sqrt{1 + \left(\frac{D_a\xi_a}{2F}\right)^2 \frac{n+1}{n-1}} - 1\right]; \qquad n = \sqrt{\varepsilon};$$

F_{V0}^2 – constant, F -lens focus, D_a - vertical dimension of the lens, ε - dielectric coefficient of the lens material.

EXPERIMENT

Using expressions (1-3) the antenna gain was analyzed and it was found, that optimal geometry of toroidal lens antenna (max gain for min lens radios a_a) is taken place when the lens edge is illuminated by biconical horn with power level some about –11,5 dB in relation to aperture center. The experimental prototype of such optimal omnidirectional antenna was produced and studied in the frequency range 18-19 GHz. The parameters of antenna were the following: radius of biconical horn - a_f/λ =1.54, vertical size of biconical horn - D_f/λ =1.82, vertical size of lens aperture - D_a/λ =6.76, lens focal ratio - F/D_a =0.73. The biconical horn with the coax to waveguide transition is showed on fig.2 and the toroidal lens antenna is showed on fig. 3. The lens and radome were produced from polystyrene with dielectric coefficient ε =2.56 and the thickness of the radome was equal to $\lambda/2\sqrt{\varepsilon}$. This provides quite small power losses ≤0.2 dB and reduces ripple of pattern power in horizontal plane. The input VSWR of the antenna -fig. 4 is not more 2 within measured frequency range and the dominant contribution in VSWR adjusts reflections from the lens, as it was found. The measured pattern power in horizontal plane at 18.5 GHz is calibrated in dBi and showed on fig. 5. As one can see the max gain of the antenna is 9.5 dBi and ripple is not more then 1.5 dB.

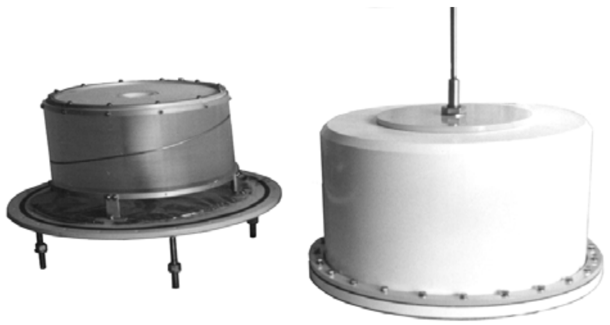

Fig.3 Photo of the toroidal lens omni antenna

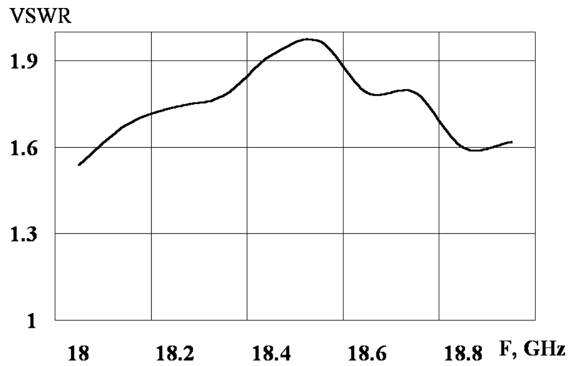

Fig.4 Input VSWR of the omni antenna

Frequency ripple within main lobe is about 1 dB peak to peak and cross-polarization in horizontal plane is smaller than –17 dBi. The normalized pattern power in vertical plane was also measured at 18.5 GHz and showed on fig. 6 (smooth curve) jointly with the calculated one (dotted curve). The conformity between measured and calculated data is good within the main lobe as high as –20 dB, but in the area of side lobes the measured data is quite higher then calculated data due to the influence of antenna mounting construction elements. Frequency ripple within main lobe also is not more than 1 dB peak to peak and cross-polarization is about –15 dBi. To provide electrical contact between lightning and current lead the copper wire was used and total resistance of electrical circuit is not more than 0.01 Ohm.

CONCLUSIONS

1. The construction of the microwave omnidirectional antenna was proposed and formulas for calculating radiating characteristics were obtained;
2. The optimal geometry of an omnidirectional antenna was formulated and prototype was designed and produced in 18 GHz band;
3. The experimental study of the omnidirectional antenna was executed and it was showed that calculated and measured data is in a good agreement.

REFERENCIES

[1] K. S. Kelleher, C. W. Morrow, “Omnidirectional circularly polarized antenna”, *IRE Conv. Record,* Part 1, pp. 28-31, January 1955.
[2] A. L. Teplyuk, G.I. Khlopov, “A Study of Biconical Horn Antenna”, in press.
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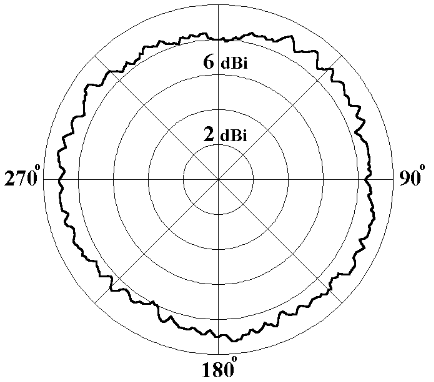

Fig. 5. Pattern power in horizontal plane

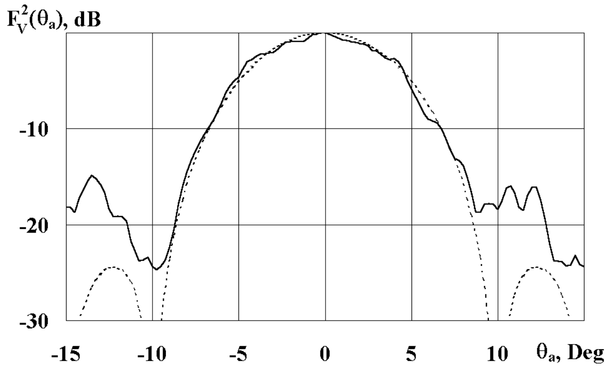

Fig. 6. Pattern power in vertical plane