Modelling of broadband 1-18 GHz antipodal dual-polarized Vivaldi radiators for antenna array

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Abstract. Four models of 1–18 GHz antipodal Vivaldi radiators with dual orthogonal polarizations as part of the infinite antenna array (AA) are considered. The models have antipodal location of printed conductors on two sides of a substrate in tapered slot part of the antenna; elliptic resonators and a symmetry plane passing through a diagonal of Floquet’s unit cell. For VSWR lowering and improvement of isolation of orthogonal channels at resonance frequencies the models can contain the rectangular plates or rods of an absorber. The best model of the radiator AA with long absorber rods has VSWR not higher than 2.55 and an isolation of orthogonal channels more than 19 dB.

1. Introduction
A problem of the creation of the video impulse antenna arrays (AA) is associated to the analysis and selection of radiators of ultrashort pulses of electromagnetic (EM) field [1–4]. Also it should be taken into account (and if it is possible to use) the electromagnetic interaction between the radiators both in outer EM field and in the feeding system [2]. The problem becomes complicated if an AA should operate with two orthogonal polarizations [5].

In this report several models of antipodal ultra-wideband Vivaldi radiators with dual orthogonal polarizations as part of the infinite AA are considered. Numerical simulation of radiators was executed using Ansoft HFSS.

2. Model 1 of Vivaldi radiators with metal rods
Model 1 of Floquet’s unit cell of antipodal Vivaldi radiator (AVR) with dual-orthogonal linear polarizations consists of two orthogonal radiators (the left part of figure 1) and has two input connectors with fragments of the coaxial cables. Two Rogers Ultralam 2000™ substrates (ε = 2.5, tgδ = 0.0019) have thicknesses of 0.5 mm and lengths of 95 mm. The radiator has antipodal location of printed conductors on two sides of a substrate in tapered slot part of the antenna and elliptic resonators. The resonator profile is part of an ellipse with ellipticity of ell₁,₂ = 2r₁,₂/(d – w) (in this model r₁ = r₂; ell₁,₂ = 0.75 – 1.3). The simulation considers the thicknesses of printed conductors of 35 µm.

The right part of figure 1 shows compact package of two orthogonally located Vivaldi’s radiators in one Floquet’s unit cell. Radiator design has a plane of symmetry passing through a diagonal of the Floquet’s unit cell. Thus the conditions of the excitation of two orthogonal channels (Port 1, Port 2) are identical, it is essentially important for alignment of phase characteristics of channels [5]. The model includes the shield for mounting of radiators.
On the long edges of substrates the metal rods connecting among themselves adjacent radiators take place. They are intended for elimination of the anomalies of VSWR at resonance frequencies [2]. Absorbing boundary conditions were set on rather remote face surface of the radiator Floquet’s cell for increase of decision accuracy at low frequencies.

The form and the sizes of radiators, the location of a resonator, the form and the resonator sizes, the lengths of metal rods were variable parameters. Figure 1 and table 1 show the dimensions for model 1 of the AVR unit cell resulting from the optimization.

**Table 1.** Final radiator parameters design.

| Parameter | d | h₁ | h₂ | r₁ | r₂ | w |
|-----------|---|----|----|----|----|---|
| Dimension (mm) | 9.4 | 80 | 15 | 2.96 | 2.96 – 5.14 | 2.96 – 5.14 | 1.5 |

The main characteristics of radiator model 1 as a part of the infinite AA in a band of 1 – 20 GHz are given in figure 2. Calculation precision after 7th steps, when the construction was divided on 237539 tetrahedra, was 0.008.

**Figure 2.** VSWR for models 1 (left) and isolation of orthogonal channels of a single AVR as part of the infinite AA for models 1 and 2 (right).

VSWR on inputs of a radiator (the left part of figure 2) has some maxima caused by resonances of a field. The field intensity in the region of the resonator of the active channel of a radiator sharply increases at several resonance frequencies. The resonator of the passive channel is intensively excited (figure 3) and the isolation of orthogonal channels |S₁₂| sharply decreases to a minus of 4 dB (blue line on the right part of figure 2). In the passive channel two waves running from the resonator (as from a source) in different directions are formed. At resonances the intensity of the E-field can increase on the edges of two resonators (see the left part of figure 3) and on the edges of conductors (the right part of figure 3). Though the efficiency of a radiator isn’t worse than 80 %; its application is limited by the isolation of orthogonal channels.
3. Model 2 of the radiator with the absorber plates
In the second model of a Vivaldi radiator (figure 4) in addition to metal rods the rectangular plates of absorber (0.2 mm thick) in the middle of two resonators are placed for blanking of high-Q resonances. The simulation showed that VSWR doesn't exceed 2.5 in operating band of 1 – 18 GHz, but absorber plates eliminate only some anomalies of VSWR (figure 5). The absorber plates improve the isolation of channels (on 4 dB; red line in the right part of figure 2), but the efficiency is slightly reduced (in comparison with model 1). We will mark that the introduction in resonators of similar metal filtering plates (instead of the absorber plates) doesn't remove the resonances.

4. Model 3 of the radiator with the short absorber rods
Model 3 differs from the previous by a form of a contour of the resonator and a placement of an absorber. Front, also elliptic, longer part of the resonator with other ellipticity of the contour \( e_{l1} = 1.5 – 4.5 \) is added. The contour of back part of the resonator (near to the input connectors) is still described by ellipticity \( e_{l2} = 0.75 – 1.5 \). The absorber rods are located from the resonator until the end of the radiator (instead of metal rods). Remaining geometrical parameters of the radiator are as in the previous model.

Existence of the absorber rods leads to VSWR lowering almost in all range of frequencies (the left part of figure 6). The isolation between channels increases and it isn't worse than 12 dB (the right part of figure 6). However, the radiator efficiency considerably decreases because of the big area of the absorber.

5. Model 4 of the radiator with the long absorber rods
In model 4 the absorber rods have the cross section of 1.25 mm×1.25 mm, length of 92.5 mm. They pass from shield through the resonator prior to the beginning of the substrate. The ellipticity of a profile of the resonator, as in model 2, varies within the limits \( e_{l1} = e_{l2} = 0.75 – 1.5 \).

Model 4 possesses the best characteristics in case \( e_{l1} = e_{l2} = 0.75 \) for the cross size of the Floquet’s unit cell of \( d = 9.2 \) mm; VSWR on two inputs of the radiator isn’t higher than 2.55 (the left
part of figure 6). The maximum value of the realized gain of one radiator increases from a minus of 20 dB to plus of 2 dB in a band of 1 – 18 GHz (the left part of figure 7). The polarizing isolation of two orthogonal channels of model 4 makes more than 19 dB (the right part of figure 6). Phase-frequency characteristics of two channels of this model coincide with graphic precision. A disadvantage of model 4, as well as model 3, is the low efficiency at the upper frequency range (the right part of figure 7). However, it isn’t worse than for model 3 (the right part of figure 7).

![Figure 6. VSWR (left) and isolation of orthogonal channels (right) of a single AVR as part of the infinite AA for models 3 and 4.](image)

![Figure 7. Gain, directivity for model 4 (left) and efficiency (right) of single radiator as part of the infinite AA for models 3 and 4.](image)

6. Conclusion
Four models of antipodal Vivaldi radiators from 1 GHz to 18 GHz with dual orthogonal polarizations as part of the infinite antenna array were considered. At the model with metal rods very weak isolation of orthogonal channels is observed. The model of the radiator with long absorber rods has the best characteristics of VSWR not higher than 2.55 and the isolation of orthogonal channels more than 19 dB, but has the worst efficiency. The model with the rectangular plates of the absorber in the resonator can be a compromise in operating band of 1 – 18 GHz.

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References
[1] Baum C E and Farr E G 139 Impulse radiating antennas in Bertoni H 1993 Ultra-wideband, short-pulse electromagnetics (Plenum Press)
[2] Shin J and Schaubert D H 1999 IEEE Trans. on Antennas and Propag. 47 879
[3] Schantz H 2005 The Art and the Science of Ultrawideband Antennas (Artech House, Inc., USA)
[4] Qing X, Chen Z N and Chia M Hindawi Publishing Corporation. Int. J. of Antennas and Propag. Vol 2008 Article ID 267197
[5] Yukhanov Y V, Privalova T Y, Semenikhin A I and Semenikhina D V 2012 15th Int. Symp. on Antenna Techn. and Appl. Electromag. (ANTEM) (Toulouse/ France)