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Radiating Element Based on the Two-Wire Line with Horns

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Abstract: *The radiation element based on the two-wire line with "horns" is considered. Additionally, a "horn" element was made to reduce the reflection of the antenna, which affected the VSWR and directional diagrams. VSWR in the range from 1.1 GHz to 8 GHz is below three. Antenna gain at frequencies from 2 GHz to 8 GHz is in the range from 4 to 22. The width of the directional patterns from 2 GHz to 8 GHz decreases from 59 degrees to 18.5 degrees.*

Index Terms: *UWB antenna, radiating element.*

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I. Introduction

UWB application has been used to create safe environment for people in their large cluster. Under the NATO SPS Program and Grant G4992, radar is being developed to determine the presence of hidden weapons on the human body from the size of 2-3 to 40-50 centimeters. The UWB antenna is required in this device to transmit a pulse signal without distortion, signals with a wide spectrum of frequencies. Currently, several types of radiating elements are used for UWB applications. Here we focus on two types of radiating elements - Vivaldi and the "bow-tie".

In particular, antennas based on radiating elements of the Vivaldi type have such features:

- it is long and expensive process of calculating, manufacturing and bringing to the given conditions;
- antenna characteristics are calculated using the CST Microwave Studio or other packages;
- the manufacture of antennas requires the presence of microwave technology on a surface with a large area; it is necessary to have an appropriate volume of chemical reagents and an operating chamber.

The "Bow-tie" antennas have the following features:

- the significant dependence of the radiation characteristics on the angle of the antenna overlap, as well as the need for using a high impedance feeder (the maximum operating frequency band (86%) was achieved at a 150-200 ohm [1];
- expansion of the working frequency band due to the use of resistive [2] and capacitive [3] load significantly complicates the antenna, reduces efficiency and makes it unsuitable for use in small telecommunication devices;
- a low gain of 1.5 dB [4];
- the antenna is fed by a coaxial or coplanar or strip line; advantages: high emitting efficiency and simple manufacturing [5];
- the production of capacities is implemented in the form of cuts, which is a complex technological process [6].

Antennas based on the two-wired line have the following features:

- the impedance of the two-wire line is determined according to the exact simple formula;
- the formula for the impedance of the two-wire line is easy to wrap against its dimensions;
- the impedance of the two-wire line is a function of one parameter - the ratio of the distance between the axes of the wires to the diameter of the wires; this greatly simplifies the process of synthesis of the antenna with given parameters;
- the two-wire line based antenna is a symmetric device. To simplify the experiments, it can be easily rebuilt into an asymmetrical antenna with half of impedance (the antenna symmetry plane is an electric wall);
- to reduce the weight of the antenna, the wires can be replaced by tubes.

  In this paper radiation element based on the two-wire line with "horns" is considered. Simulation and measurement result are consistent.

II. Two-Wire Antenna Design

In general, two-wire antennas are constructed with different characteristics of the distribution of impedance along the length of the antenna. Some of them are: exponential, Chebyshev, compensatory. An example of a compensatory antenna is shown in Fig. 1. Equation (1) describes the dependence of the impedance on the length and the shape of the compensatory antenna.

$Z(x) = 100 \cdot \exp(\ln(120\square\square/100) \cdot x \cdot (1 - \square\square \cdot \mathrm{sinc}(2\square\square x))\square\square\square$

where $\square\square = 0.3875\square\square$ Equation (2) describes dependence of the distance between the axis of symmetry of the antenna and the center of the wire.

$A(x,Z) = \cosh(Z(x)/119.004 \cdot \exp(x \cdot \ln(120\square/Z(x))\square\square\square$

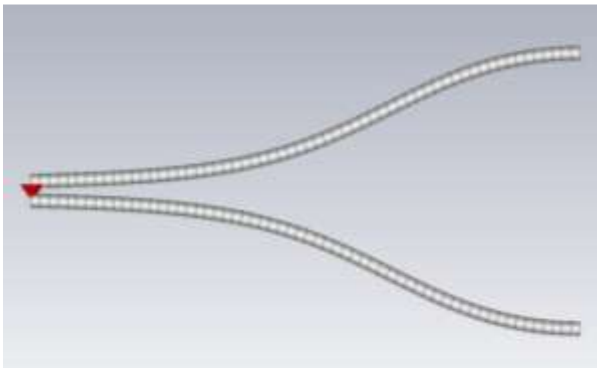

Fig. 1 Compensatory antenna

The axial current at the end of the wire should be zero. If at the end of the wire a wave arrives with non-zero amplitude, then reflection is formed, which leads to an increased VSWR. It is advisable to remove this effect. “Horn” added for this. The length of the "horn" is chosen so that the magnitude of the current at the end of the wire is as small as possible. "Horn" is formed by part of the ellipse, which is constructed by a parametric equation (3).

$y(t) = y_0 + a_y \cdot \cos(t + \square_x)$ (3)

$x(t) = x_0 + a_x \cdot \sin(t + \square_x\square$

where $t = 0..2\square\square$

"Horn" in Fig. 2 is 94.7 mm length, the width between the antenna wire axis in the beginning – 10.95 mm, at the end – 209.49 mm. The length of the antenna along the axis of symmetry without a horn is 357.87 mm. The diameter of the wire is 8 mm.

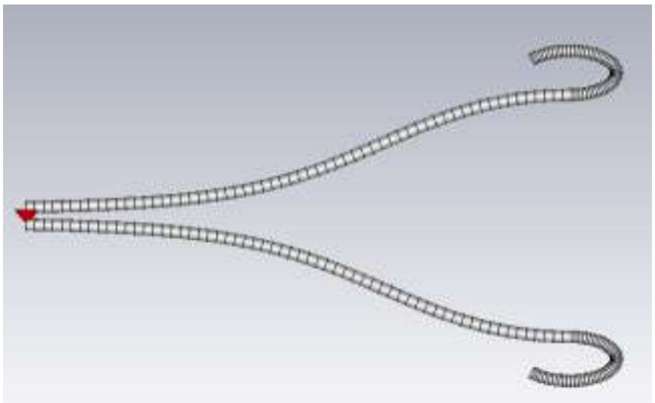

Fig. 2 Compensatory antenna with "horns"

III. Simulation Results And Measurements

The antenna was modeled in CST Microwave Studio with different lengths of "horns". The simulation was carried out in the range from 0.5 GHz to 8 GHz. Results for three values of the length of the "horn" (along the axis of the wire) are presented. The smallest is 64.52 mm, the middle is 85.16 mm, the largest is 94.7 mm.

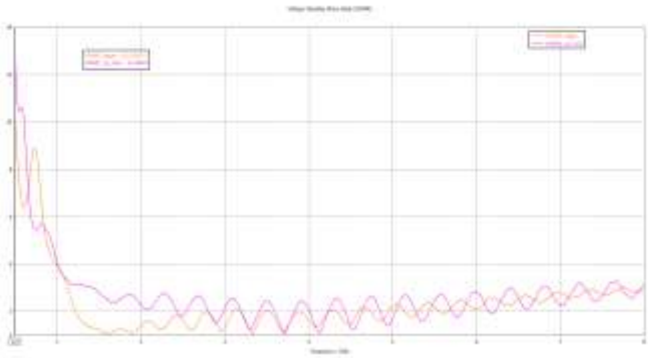

Fig. 3. VSWR for antenna without "horn" and with 94.7 mm "horn"

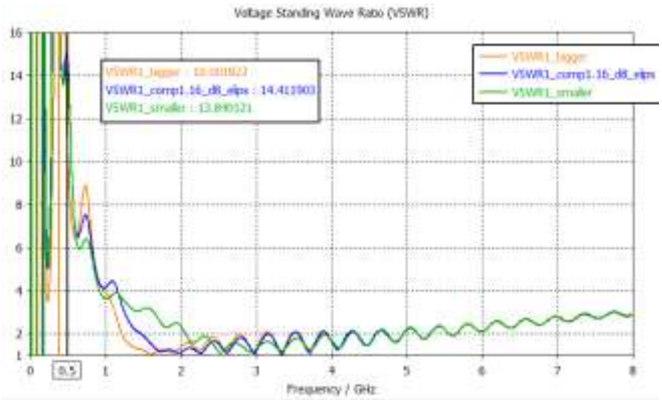

Fig. 4. VSWR of antennas with different sizes of "horns"

In the range from 0.5 GHz to 1 GHz – the improvement of VSWR is poorly demonstrated (Fig. 3 and Fig. 4). At frequencies from 1 GHz to 1.5 GHz, VSWR becomes lower: from 2-3 to 1.1-1.5 (Fig. 3). From 1.1 to 8 GHz, VSWR gradually increases from 1.1 to 3, but at the same time the amplitude of oscillations (from the upper limit to the lower one) decreases twice (Fig. 3 and Fig 4).

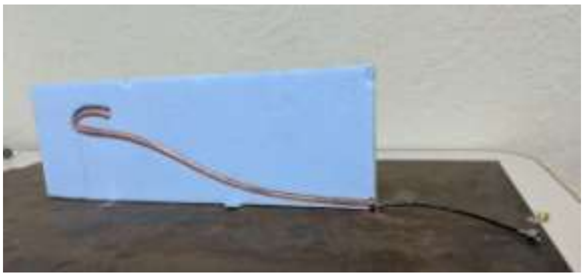

Fig. 5. Manufactured radiating element

The radiating element is made of pure copper in the thickness of 8 mm. VSWR comparison of measurement and simulation results showed on Fig. 6. Measurement is close enough to simulation results. Antenna's VSWR is less than 2.5 in the range from 1.2 GHz to 8 GHz.

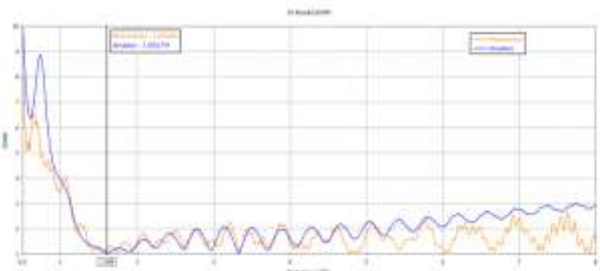

Fig. 6. VSWR simulation results (blue) and measurement (orange)

Fig. 7 shows 3-D realized directional diagrams at frequencies of 0.5, 2, 5, 8 GHz for an antenna without "horns".

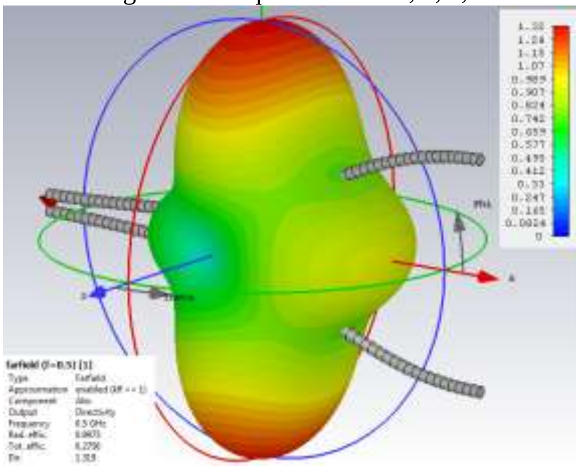

Fig. 7.1 3-D directional diagrams 0.5GHz

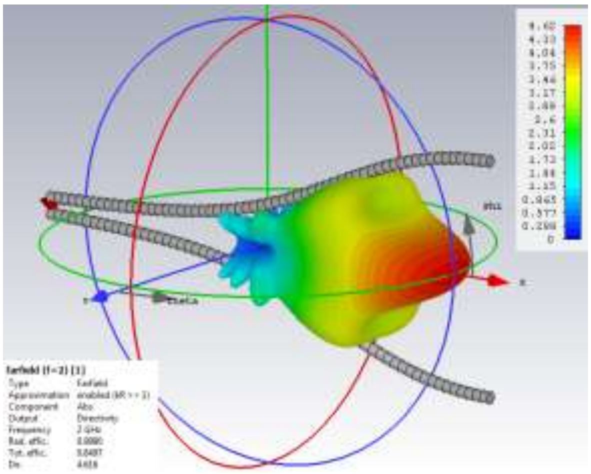

Fig. 7.2. 3-D directional diagrams 2 GHz

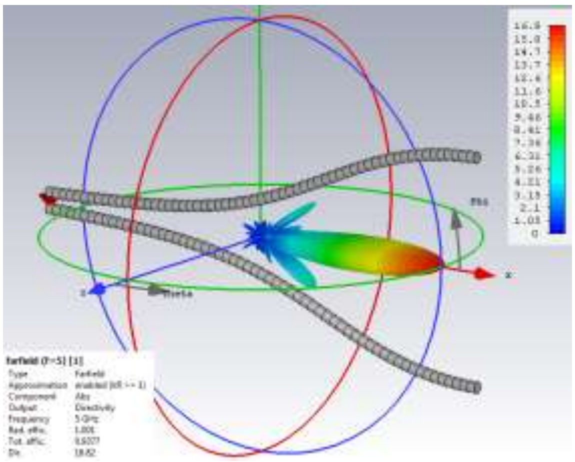

Fig. 7.3. 3-D directional diagrams 5 GHz

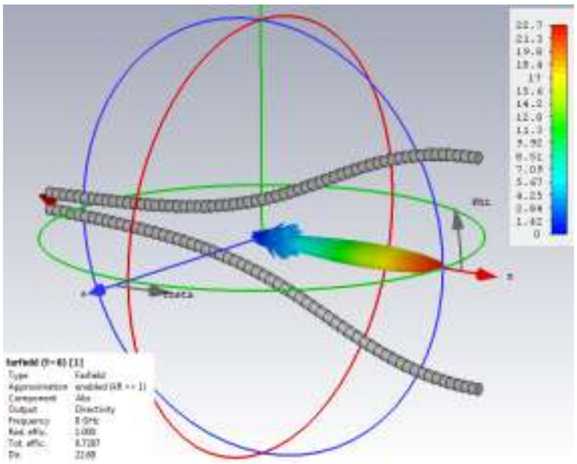

Fig. 7.4 3-D directional diagrams 8 GHz

Fig. 8 shows the 3-D directional diagrams for antenna with 94.7 mm "horn".

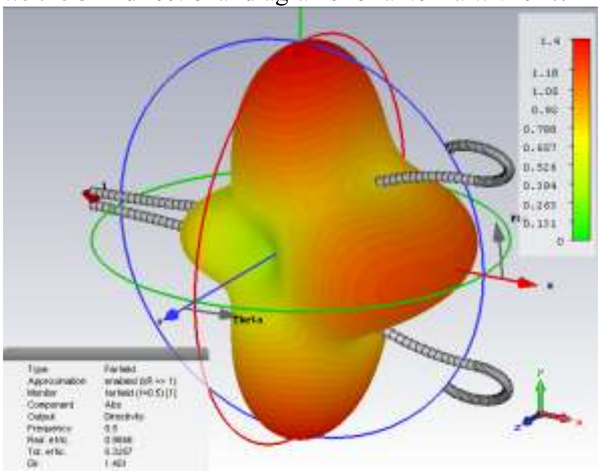

Fig. 8.1. 3-D directional diagrams 0.5 GHz

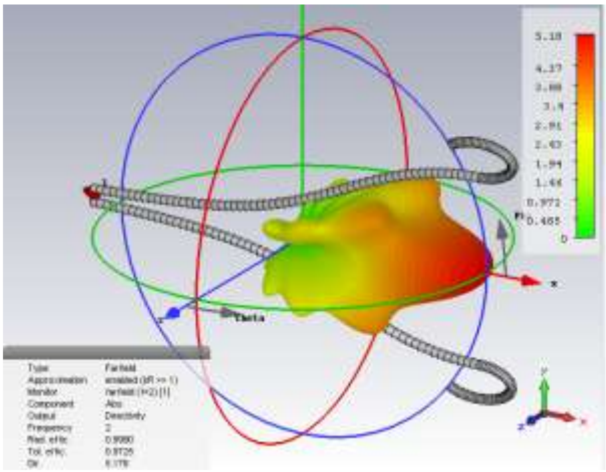

Fig. 8.2 3-D directional diagrams 2 GHz

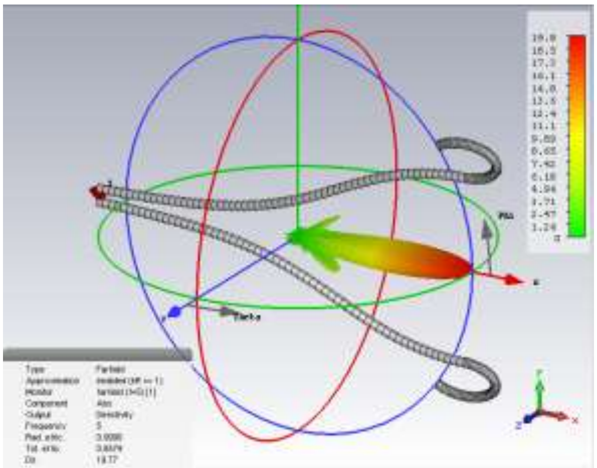

Fig. 8.3 3-D directional diagrams 5 GHz

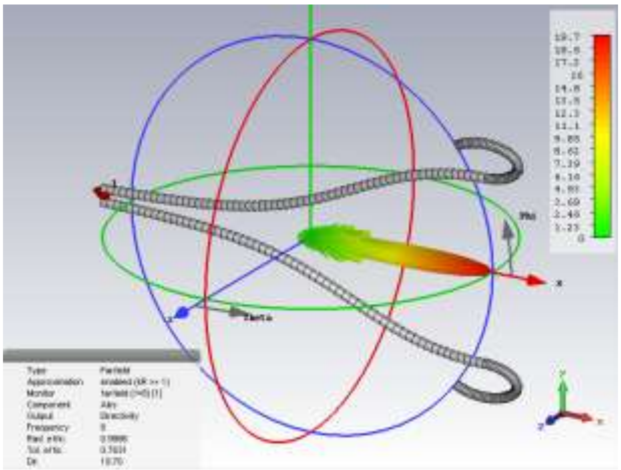

Fig. 8.4 3-D directional diagrams 8 GHz

In Fig. 7 it is evident that at a frequency of 0.5 GHz the antenna without "horns" radiates mainly along the Y axis. With the addition of "horns" at a frequency 0.5 GHz the amplitude of radiation in the Y direction has become smaller. In addition, the presence of "horns" leads to a narrowing of the directional diagrams at all frequencies, as can be seen from the table 1.

TABLE I. WIDTH OF THE DIRECTIONAL DIAGRAM (UNIT: DEGREES)

Freq., GHz	**In Theta plane (phi = 0) / in Phi plane (theta = 90)**	
	Without “horns”	**With “horns”**
0.5	N.a. / ~100	145 / 90
2	70 / 81.6	59 / 65.8
5	33 / 15.7	28.6 / 14.3
8	22 / 10.8	18.5 / 10.6

IV. Conclusion

This paper describes the UWB two-wire antenna with VSWR below three in the frequency range from 1.1 GHz to 8 GHz and with a narrowed directional diagram. The presence of "horns" leads to a narrowing of the directional diagrams at all frequencies comparatively with antenna without “horns”.

Acknowledgment

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