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HB9CV ANTENNA: THEORETICAL AND PRACTICAL ASPECTS

Tomislav Barić[1], Hrvoje Glavaš[1], Ljiljana Radovanović[2]
[1]University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Osijek, Croatia
[2]University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
e-mail: hrvoje.glavas@ferit.hr

Abstract: Due to its excellent electromagnetic and electrical characteristics, compactness, and ease of manufacturing, the HB9CV is one of the most popular antennas among radio amateurs. In its simplest form, the HB9CV consists of two unequal length dipoles that are fed by phasing lines. This makes both dipoles active elements. By using two active elements in the HB9CV antenna, instead of one as in the Yagi antenna, a higher gain is achieved for the same physical dimensions of the antenna. Since the first introduction of the HB9CV antenna until today, radio amateurs have developed numerous versions of the HB9CV antenna. Most versions of HB9CV antennas use additional parasitic elements for the reflector and directors. In this paper, a review of the HB9CV antenna family is given. The electromagnetic characteristics of HB9CV antennas with two elements and with four elements (two active and two parasitic elements) were analyzed using 4NEC2 software and presented in detail. The four-element version of the HB9CV antenna was assembled. The electrical parameters of the assembled antenna were measured with a vector analyzer and presented.
Key words: antenna, directional antenna, HB9CV antenna, radio amateurs

INTRODUCTION

The popularity and widespread use of a particular type of antenna among radio amateurs depends on several factors. The antenna must have good electromagnetic and electrical characteristics and should be relatively simple to assemble [1, 2]. Since the dimensions of the antenna are proportional to the operating wavelength, today radio amateurs prefer to work on very high frequency (VHF) and ultra high frequency (UHF) because the antennas are significantly smaller in VHF and UHF compared to the once popular high frequency (HF) [1-4]. Also, the antenna must have sufficient mechanical durability to withstand wind blows if it is stationary and accidental impacts if it is a portable antenna [5], or the antenna is used in confined spaces [6] and stressful situations [7]. Also, radio amateurs rarely own expensive tools for working with metal, wood and plastic, nor do they have much experience in working with them. For this reason, radio amateurs prefer antennas that do not require expensive and specialized tools. Radio amateurs also prefer that the tools used in making antennas do not require much experience in their use.

Several types of antennas satisfy the above. Among the most famous are: dipole antenna, ground plane antenna, Yagi antenna family, Quad antenna family and HB9CV antenna family [1-4]. This paper will describe in detail directional antenna called HB9CV [1-4]. HB9CV antennas are typically used on very high frequencies (VHF) and ultra high frequencies (UHF) and are also popular as portable direction-finding devices. In this paper, a review of the HB9CV antenna family is given. The electromagnetic characteristics of HB9CV antennas with two active elements and with four elements (two active and two parasitic elements) were analyzed using 4NEC2 software [8] and presented in detail. The selected operating frequency for both antennas is 446 MHz (also known as professional mobile radio or private mobile radio (PMR)). The four-element (two active and two parasitic elements) version of the HB9CV antenna was assembled. The electrical parameters were measured with a vector analyzer and presented. The four-element version of the HB9CV antenna was assembled. The most important steps in the assembly process, the materials used and their dimensions are described and commented. The electrical parameters of the assembled antenna were measured with a vector analyzer and presented.

HB9CV ANTENNA

The HB9CV antenna was developed in the 1950s by radio amateur Rudolf Baumgartner from Switzerland with the call sign HB9CV, after which the antenna was named. In its simplest form, the HB9CV, also known as Swiss antenna, consists of two unequal length dipoles that are fed by a matching device, i.e. phasing lines (Fig. 1). The distance between the two dipoles is one-eighth of a wavelength (1/8λ) (Fig. 1). According to the construction, the HB9CV antenna resembles the ZL-Special antenna [1, 2]. Also, the HB9CV antenna can be considered a Log-periodic antenna [1] in its simplest form (only two phased elements). The HB9CV antenna can be designed as a symmetrical system suitable for feeding by balanced lines (Fig.1.a [1]), or as an asymmetrical system suitable for feeding by unbalanced lines such as coaxial cables (Fig.1.b [1]). Given that coaxial cables are currently used exclusively for antenna power supply, in this paper, the focus will be on versions of the HB9CV antennas designed as an asymmetrical system.

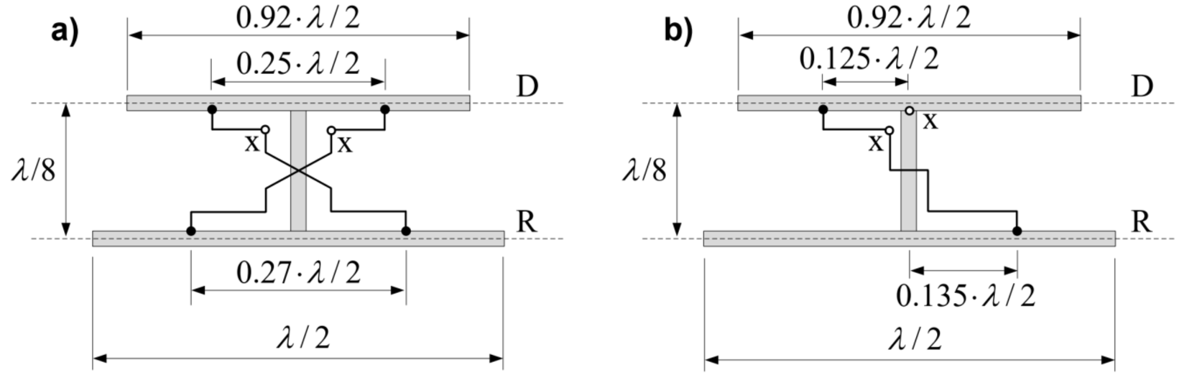

Fig. 1. *Two element HB9CV antenna, main dimensions and wiring, feeding point positions (marked with x-x) for: a) balanced lines, b) unbalanced lines*

Unlike the Yagi antenna, which has one active element (driver) that is powered by radio-frequency (RF) power, and the other elements are parasitic elements (reflector and directors), the HB9CV antenna has two active elements powered by RF power that perform the functions of director and reflector.

This approach has several advantages which can be explained as follows. Parasitic elements base their operation on the principle of re-emitting the RF energy they were exposed to. In this process of re-emitting RF energy, part of the energy is lost due to the skin effect in the conductors of the parasitic element. At the same time, parasitic elements are not exposed to all of the RF energy emitted by the active element (driver element), but only to a portion of that energy. Both of these phenomena reduce the effectiveness of parasitic elements in focusing radiation. By using two active elements (dipoles) of different dimensions and supplied with RF power with an appropriate phase shift, greater efficiency of the elements in focusing radiation is achieved. Due to the above, the HB9CV has a higher gain compared to a Yagi antenna for the same physical dimensions (boom length) [1]. Because of this advantage, radio amateurs develop a version of the HB9CV antenna with three active elements was developed. Although the HB9CV antenna with three active elements has a higher gain compared to the antenna with two active elements, and a better front/back radiation ratio, the main lobe in the radiation pattern from the front is significantly deflected from the longitudinal axis of the antenna. For this reason, this type of HB9CV antenna is rarely used, and to increase the gain and front/back radiation ratio, the use of parasitic elements is preferred.

Another advantage of the HB9CV antenna is that the dimensions of the elements of the HB9CV antenna are less critical compared to the Yagi antenna. Given that the position of the phase line connection to the elements can be made adjustable, it is possible to influence the electrical and electromagnetic parameters of the antenna.

In this way, it is possible to compensate to some extent the influence of inadequate dimensions of the antenna elements on the electrical and electromagnetic parameters of the antenna. By moving the position of the phase line connection to the elements, a point can be found where the real part of the antenna's wave impedance is exactly 50 ohms.
Almost regularly the HB9CV antenna has a reactive part of the wave impedance different from zero. However, the character of the reactive part of the antenna's wave impedance is such that it can be compensated by capacitive reactance. This can be achieved by adding a variable capacitor between one of the feeding points and the core of the coaxial cable (Fig. 2 [1]). The process of compensating the reactive part of the antenna's wave impedance, that is, improving voltage standing wave ratio (VSWR) is simple. Using a vector analyzer, the character of the antenna's wave impedance is monitored, and it is necessary to slowly change the capacitance of the variable capacitor until complete compensation of the reactive part of the wave impedance is achieved. Then it is necessary to unsolder the variable capacitor and measure its capacitance. Then, in place of the variable capacitor, a capacitor of fixed capacitance is soldered. A capacitor of fixed capacitance should have the capacitance that was measured on the variable capacitor.

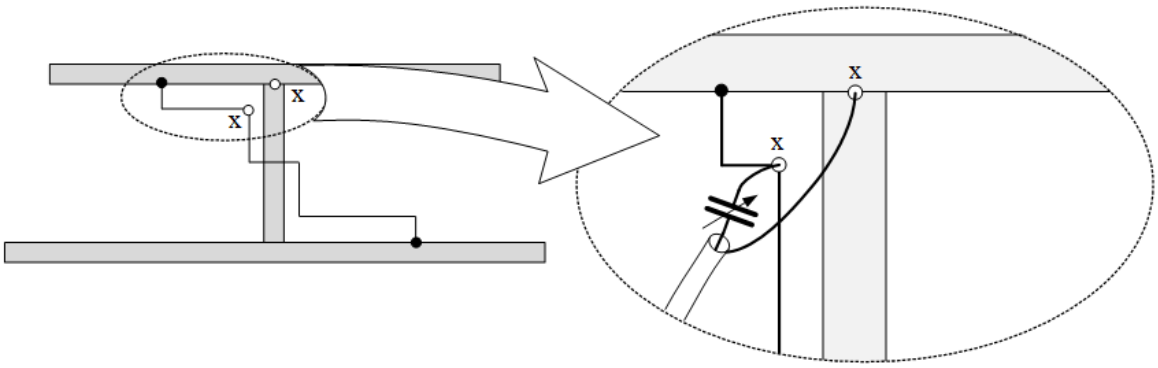

Fig. 2. *A detailed view of the feeding points and compensation of the reactive part of the antenna's wave impedance using a variable capacitor*

Since coaxial cable has a certain capacitance between the sheath and the core, coaxial cable can be used instead of a capacitor (Fig. 3). The required length is determined according to the technical data of the coaxial cable manufacturer on the capacity per unit length of the coaxial cable. Initially, a slightly longer piece of coaxial cable than necessary should be soldered, and then shortened in several steps until complete compensation of the active part of the antenna's wave impedance is achieved.

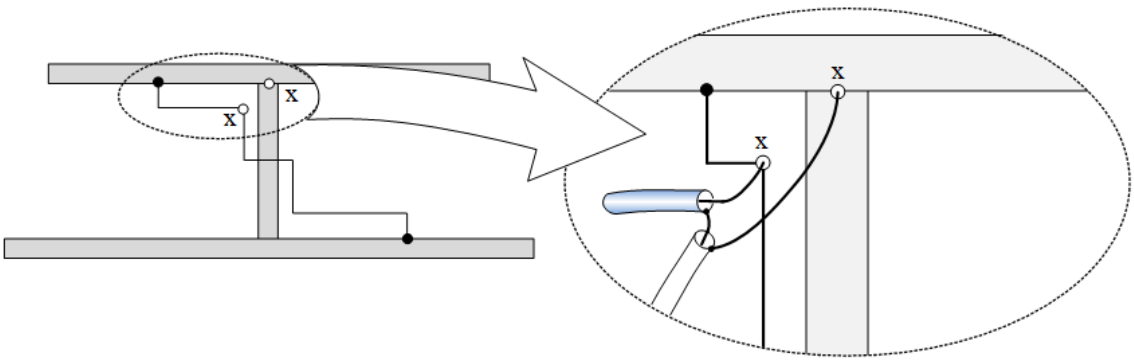

Fig. 3. *A detailed view of the feeding points and compensation of the reactive part of the antenna's wave impedance using pieces of coaxial cable*

NUMERICAL SIMULATION

Numerical calculation of the electromagnetic and electrical behavior of the antennas was carried out in the 4NEC2 software [8]. Numerical calculations were performed for the HB9CV antenna with two elements (Fig. 4.a) and four elements (Fig. 4.b). The numerical calculation was carried out for an operating frequency of 446 MHz. The obtained dimensions of the antenna elements and spacing are presented graphically (Fig. 4). The models of both antennas in the 4NEC2 software are shown in Fig. 5. The radiation diagrams are shown in Fig. 6 and Fig. 7.

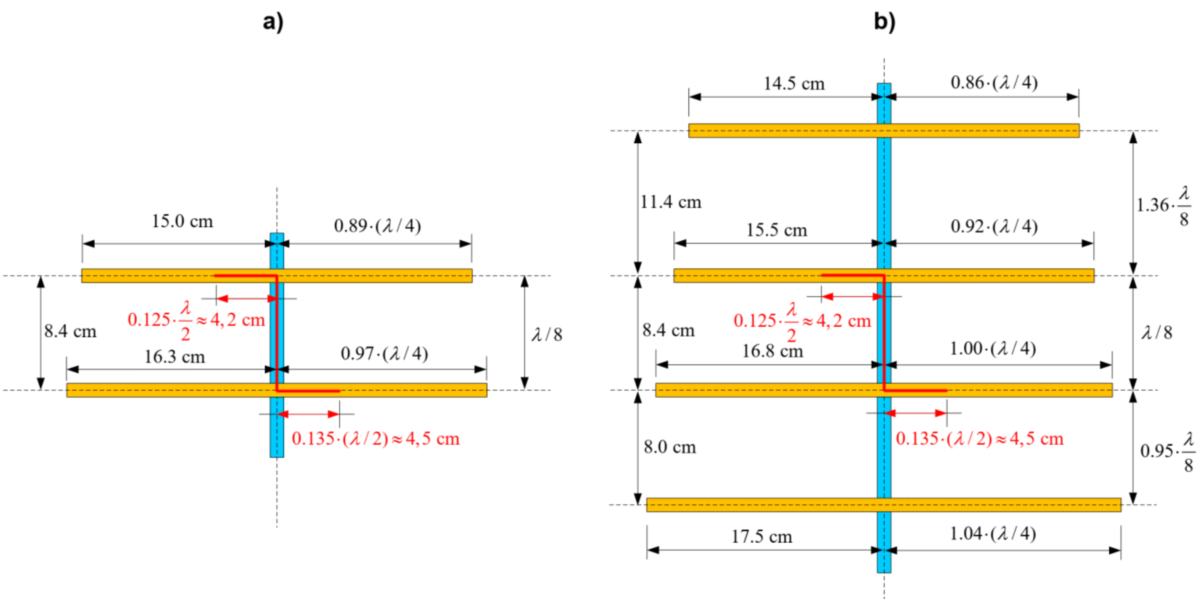

Fig. 4. *Dimensions and spacing obtained by numerical calculation for HB9CV antenna with a) two elements, b) four elements*

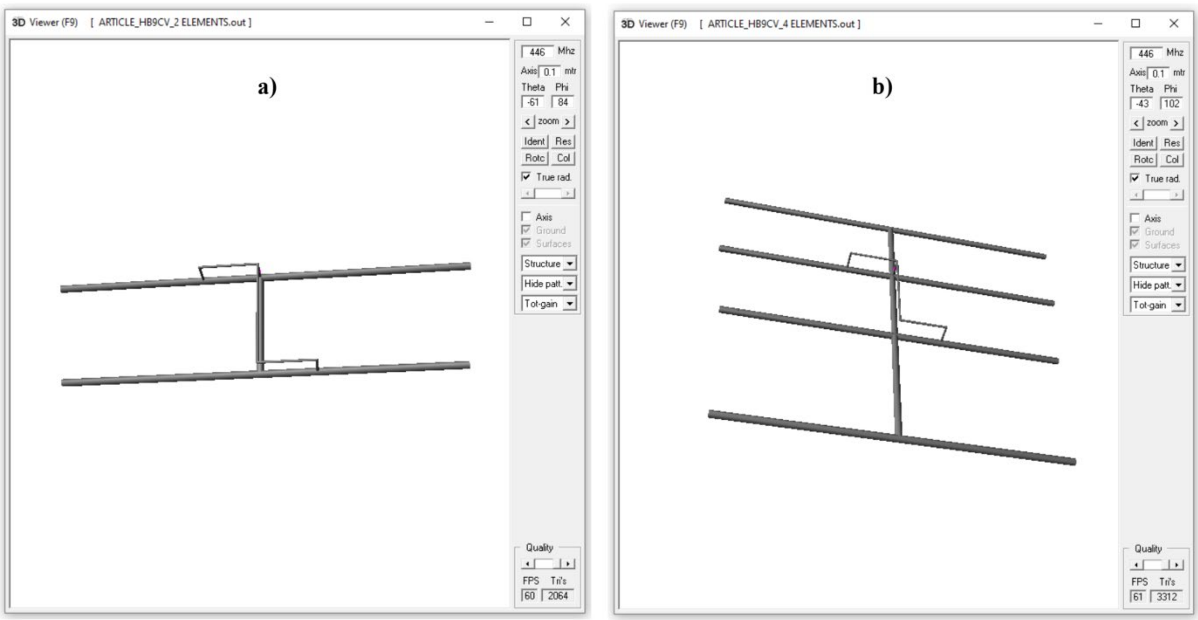

Fig. 5. *3D view of the HB9CV antenna model with a) two elements, b) four elements*

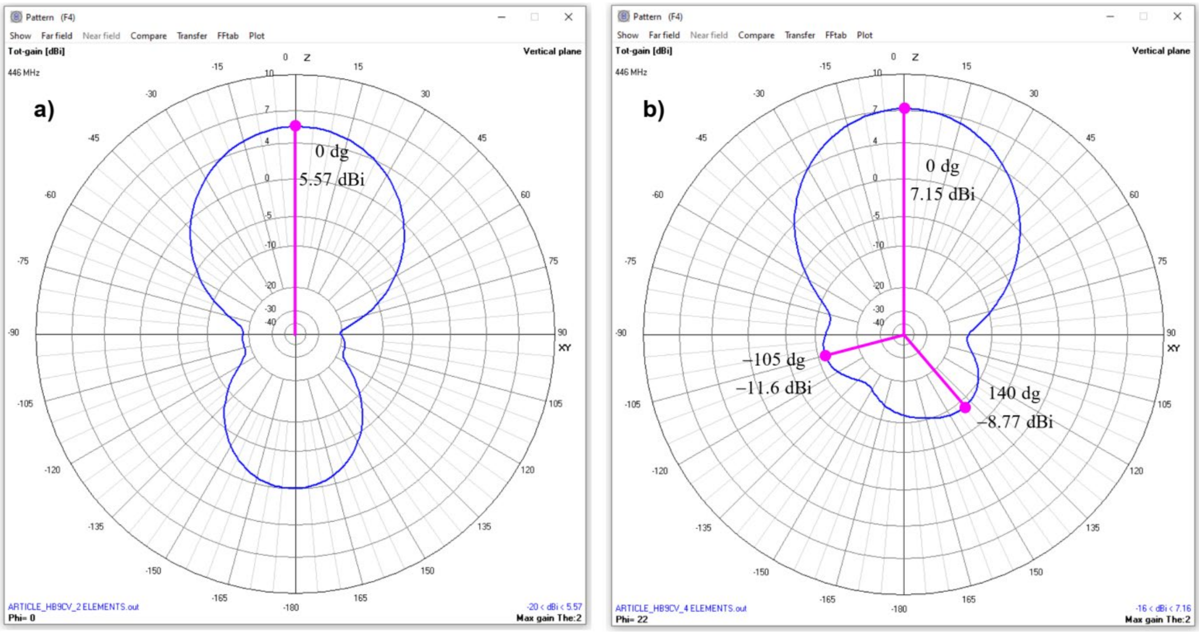

Fig. 6. *Two-dimensional radiation patterns (total gain in dBi) of the HB9CV antenna with: a) two elements and b) four elements*

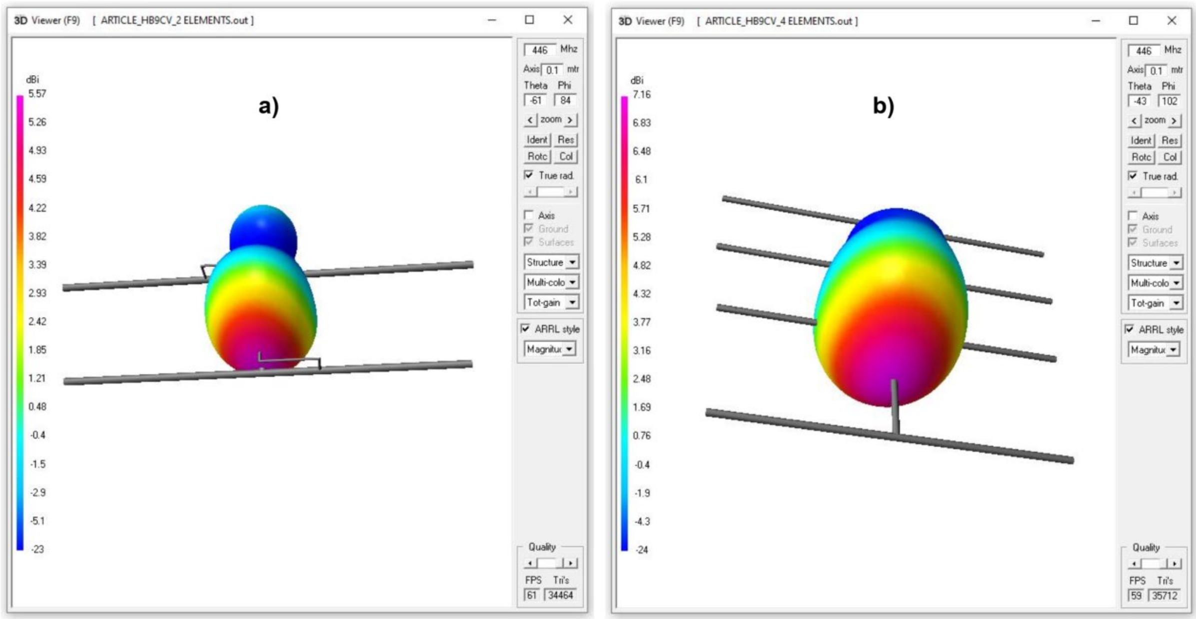

Fig. 7. *Three-dimensional radiation patterns (total gain in dBi) of the HB9CV antenna with: a) two elements and b) four elements*

ANTENNA ASSEMBLING AND PARAMETERS MEASUREMENT

On the basis of the carried out numerical calculation (Fig. 4.b), the HB9CV antenna with four elements was assembled (Fig. 8). All elements, active and parasitic are made of aluminium tube with diameter Φ=6 mm. A hollow aluminium tube with a square cross-section (dimensions of 1 cm x 1 cm) was used for the boom. The phasing line is made of solid aluminium wire with a diameter of 2 mm and is soldered to the active elements. The soldering of phasing lines and antenna elements is carried out with special electrodes for soldering aluminium [9]. A thin and very flexible RG174 coaxial cable [10], one meter long (measured from the feeding points to the SMA connector), is threaded through the handle and boom of the antenna.

In this way, the coax cable is not exposed to the radiation of the antenna elements, thereby reducing the probability of the appearance of common mode currents. Unintentional bending of the phasing lines is prevented by placing two plastic spacers (Fig. 9). Compensation of the reactive part of the wave impedance was achieved with a piece of RG174 coaxial cable with a length of 3 cm (Fig. 9). Initially, a piece of 6 cm long RG174 coaxial cable was soldered and shortened in several steps (initially by a centimetre, then half a centimetre, then in millimetres) until a voltage standing wave ratio (VSWR) at the operating frequency of 446 MHz below 1.5 was reached. The antenna, including the plastic handle and coaxial cable, weighs 160 g.

Fig. 8. *Handheld HB9CV antenna with four elements (two active elements and two parasitic elements). The antenna was assembled by the authors*

Fig. 9. *A detailed view of the plastic spacers, feeding points and compensation of the reactive part of the antenna's wave impedance using pieces of coaxial cable*

The electrical parameters of the assembled antenna were measured using the PS100 RF vector antenna analyzer meter [11]. At the operating frequency of 446 MHz, the wave impedance (after compensating for the reactive part) Z= 49.7+j17 Ohms was achieved (Fig. 10.a), which corresponds to VSWR of approximately 1.4 (Fig. 10.a). For VSWR ≤ 1.5, the bandwidth is approximately 25 MHz (Fig. 11.b), that is, for the frequency range in which the antenna operates excellently, with negligible RF power reflections. The usable bandwidth (for VSWR ≤ 2.0) is approximately 30 MHz (Fig. 10.b).

a) **b)**

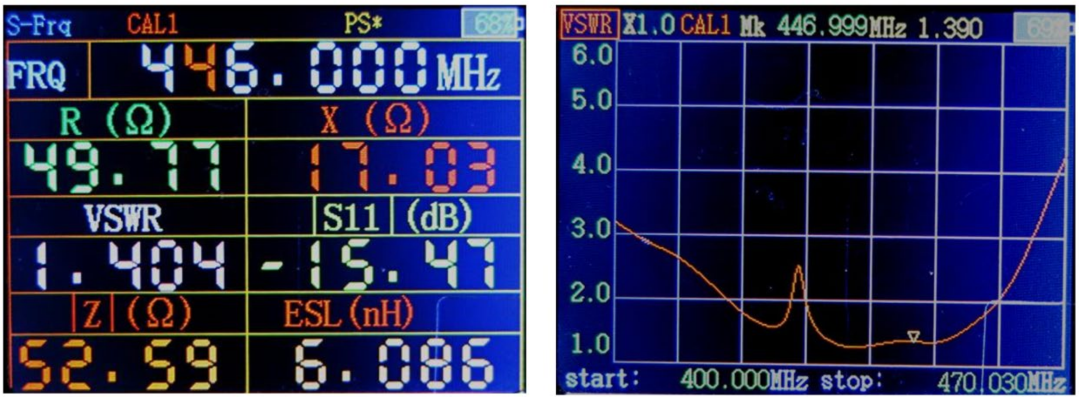

Fig. 10. *Measured parameters of a four element HB9CV antenna: a) basic electrical parameters, b) dependence of VSWR on frequency*

The gain measurement was performed by comparing the radiation intensity with a reference dipole. The measurement determined the front gain. The measured gain is approximately 1.5 decibel lower than the gain obtained by numerical calculation (Fig. 6.b). Part of the resulting difference is due to the attenuation of the RF power in the coaxial cable. According to [10], the attenuation in a one-meter-long RG174 coaxial cable is between 0.6 dB and 0.7 dB, the remaining difference is the discrepancy between the numerical calculation and the actual gain. In order to reduce RF power losses in coaxial cable, we recommend using the widely available RG58 coaxial cable [12], which has lower losses (between 0.4 dB and 0.5 dB per meter), but is slightly less flexible than RG147.

CONCLUSION

The HB9CV antenna has been around for more than seven decades among radio amateurs. Ease of manufacturing and assembly of the HB9CV antenna and HB9CV antenna family, excellent mechanical durability, and excellent electromagnetic and electrical characteristics are the reasons for its popularity and widespread use among radio amateurs. Paper demonstrated and confirmed the simplicity of the HB9CV antenna fabrication process. The HB9CV is simply tuned by moving the position of the phase line connection to the passive element and by trimming the coaxial cable, which is used as a capacitance to compensate the reactive part of the antenna's wave impedance. Also, the paper showed that adding parasitic elements to make reflectors and directors can further improve the characteristics of the basic HB9CV antenna. Adding parasitic elements to make reflectors improves the front to end radiation ratio. Adding parasitic elements to create directors improves gain and eliminates the inherent disadvantage of the HB9CV antenna of beam deflection relative to the boom axis. The aforementioned benefits of using additional parasitic elements are the reason for the widespread use of these technical solutions. In short, for all of the above reasons, the HB9CV antenna and its derivatives (HB9CV antenna family) are deservedly a very popular antenna among radio amateurs.

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