# COMPARISON BETWEEN SPIRAL ANTENNA AND MAGNETIC LOOP ANTENNA FOR THE PURPOSE OF MULTISTATIC PASSIVE RADAR

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***Abstract:*** *Recent advances in parallel computing equipment emanates from miniaturization of integrated circuits semiconductors. The result is constant lowering of the cost of computational power. This includes the initial investment expenses, the maintenance and electricity cost.*

*The development of passive radars is now possible within the boundaries of concisely sized devices, having relatively low cost for unit of equipment, low power consumption, and thus providing the availability of multi-station systems with distributed parameters that are field-deployed and battery powered. Such passive radar systems provide redundancy, better obscurity against visual identification and improved coverage of the observed area and volume.*

*A major component of any passive radar system is its antenna array. Having the modern units being small in size and well disguised, a hidden antenna becomes essential and required for such instruments. The current paper analyses two antenna candidates for passive radars by comparing their benefits and drawbacks. These are the spiral and magnetic loops antennas. Further evaluation of the suitability of these two antenna types is carried out by means of computer simulations. Conclusions are finally drawn about which type of antenna is more adequate for the purpose of small sized passive radar devices.*

# СРАВНЕНИЕ МЕЖДУ СПИРАЛНА АНТЕНА И АНТЕНА ТИП МАГНИТЕН КРЪГ ЗА ЦЕЛИТЕ НА МУЛТИСТАТИЧЕН ПАСИВЕН РАДАР

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***Ключови думи:*** *Антена за пасивен радар, Мултистатичен пасивен радар, Пасивен радар за йоносферни изследвания.*

***Резюме:*** *През последните години се наблюдава развитие на паралелните изчислителни машини, което е следствие от миниатюризацията на полупроводниците в интегралните схеми. Резултатът е постоянно намаляване на цената на изчислителната производителност, както по отношение на първоначалните разходи за инвестиция, така и във връзка с поддръжката и разходите за електроенергия.*

*Разработването на пасивни радари сега е възможно в рамките на малки по размери устройства, които консумират понижени количества електроенергия и така предоставят възможност да се изградят системи за пасивни радари, състоящи се от множество станции в разпределена парадигма, които са инсталирани при полеви условия и се захранват от батерии. Такъв пасивен радар гарантира множественост на звената, при което отпадането на някои звена от системата не води до нейното дефектиране. Друго предимство, което следва от миниатюризацията е по-доброто прикриване на модулите от визуална идентификация и по-големият обхват на наблюдаваната област и обем.*

*Основен компонент на всеки пасивен радар е антенният масив. При условие, че модерното устройство е малко по размери и добре скрито се стига до нуждата от неголяма антена, която също да може да се прикрие добре. Настоящият доклад анализира два типа антени, подходящи за пасивен радар като сравнява техните предимства и недостатъци. Това са спиралната антена и антената тип магнитен кръг. По-нататък чрез компютърни симулации се оценява до колко тези два вида антени са подходящи за малки по размери станция за пасивен радар.*

## Introduction

The passive radar is a type of radar. As any radar system it detects, identifies and tracks objects flying in the sky or traveling or sailing on the surface. A classical radar would emit radio waves and then wait to receive reflections carrying information. This system is called active radar. Passive radars would instead rely on existing radio transmitters developed and maintained by other parties not in any relation or knowledgeable of the passive radar system that is in use [1]. Such radio transmitters are called transmitters of opportunity or non-cooperative transmitters (Fig. 1). The passive radar receiver accepts reflected and direct waves from the transmitters of opportunity and is required to distinguish between them [2]. This process as well as the identification, tracking and classification of targets is possible through appropriate computations [3–5]. These computations have massive character and generally require modern parallel computing hardware.

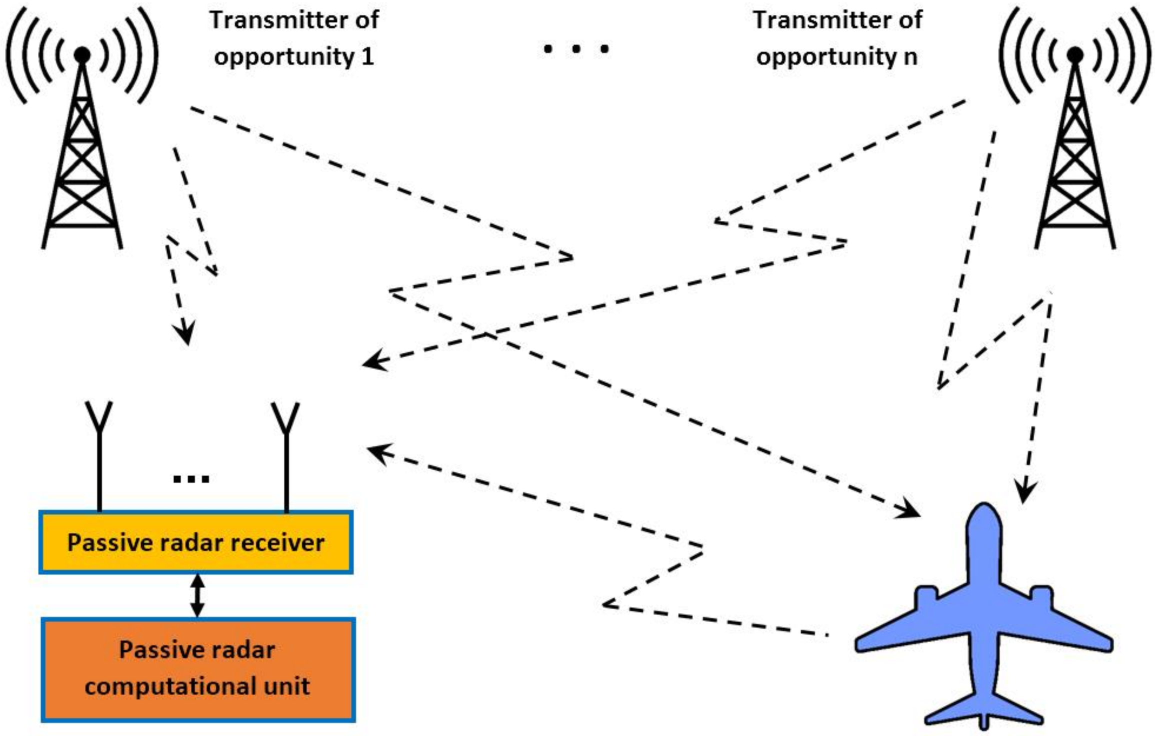


Fig. 1. Passive radar system

Targets that can be observed by passive radars are objects of various sizes. Even the ionosphere is an object that is being studied scientifically by passive radars [6-9]. Any radio wavelengths are suitable for passive radar implementation with some limitations. For example, to study the ionosphere, lower frequency band radio emissions are more applicable such as the high frequency (HF) and very high frequency (VHF) bands. Potential transmitters of opportunity over the Bulgarian territory are the mobile phones and other mobile communications base stations, digital TV stations, FM radio broadcasting transmitters, etc.

It should be mentioned that passive radars are bistatic and multistatic. The first kind makes use of a single receiver and a single transmitter. Multistatic counterparts employ more than one non-cooperative transmitters and/or receivers. All of the transmitters and receivers are spread over considerable area.

## Spiral antenna and magnetic loop antenna for the purpose of multistatic passive radars

In the territory of Bulgaria, most suitable transmitters of opportunity, for most purposes, are the FM broadcasting transmitters, either located within the country or positioned in the neighbouring countries. The frequency band is from 87.5 to 108 MHz. As the wavelength is inversely proportional to the frequency, the lower the frequency is, the longer the wavelength. For the band of interest the wavelength is about 3 meters.

There are a few requirements for the small sized passive radar station antenna, some of which were mentioned earlier in this article, namely:

1. To be easily concealed

2. To be employed at a wide range of frequencies
3. To have a rigid construction
4. To possess low wind resistance
5. To have a wide gain pattern with no lobes
6. To exhibit lower interference with local electromagnetic interference sources

While analysing antenna types we realize that only two antenna families satisfy requirements 1, 3 and 4. These are the planar and shortened antennas. To fulfil requirement 2 and 5 we have to still narrow the possible variants. Either a wideband antenna should be used or an electronically tuneable shortened antenna. This lands us at three choices: a planar spiral wideband antenna, a shortened dipole or a small loop antenna also known as magnetic loop antenna. Trying to respond to requirement 6 we abandon the shortened dipole in favour of the magnetic loop because the latter exhibits better noise immunity to local interference (Fig. 2).

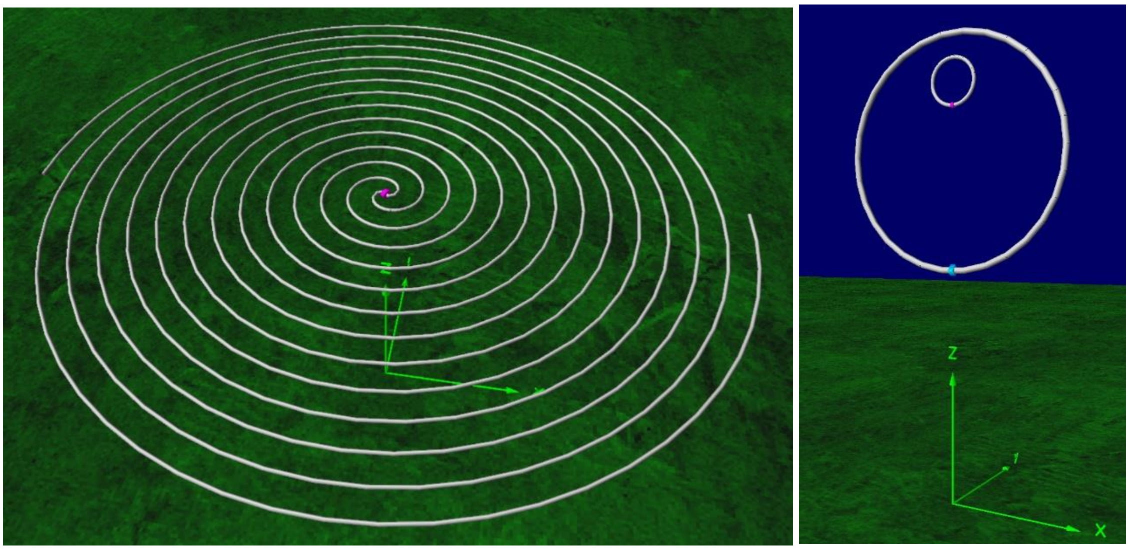

Fig. 2. 3D structure of the spiral antenna (left) and magnetic loop antenna (right)

The spiral antenna is a wideband antenna (Fig. 2, left) while the magnetic loop (Fig. 2, right) is a very narrow band antenna. In Fig. 3 one could examine spiral antenna impedance and standing wave ratio in respect to frequency. The same characteristics for the small loop antenna are shown in Fig. 4. Both charts are generated using a software for antenna simulation and analysis 4NEC2. This software is freeware, performs well and has good features. For these reasons it has become widely used in antenna design and antenna analysis tasks.

The spiral antenna comes in different flavours such as Archimedean spiral, logarithmic spiral, square spiral, star spiral and so on. It is a balanced type of antenna having its feed point in the centre and its impedance mostly constant for frequencies above a certain cut-off frequency. Its radiation pattern and polarization are also mostly constant above this frequency. This type of antenna may be used with or without a reflector, but for the purpose of local interference shielding a reflector is a must.

Spiral antennas are travelling wave antennas, hence they are wideband, but they also exhibit the other principles of operation: fast wave and leaky wave. The fast wave in these antennas is a result of mutual coupling between spiral arms. Radiation is realized through the leaky wave phenomenon. The working principle of the spiral antenna is given by ring theory or band theory, according to which spiral antenna's radiating active region is the geometric circle having circumference equal to the wavelength [10].

The impedance is defined by the geometrical properties of the device. By choosing the ratio between the spiral conductors and its spacing on one hand, and the distance from the reflector on the other hand, a certain impedance could be achieved. The polarization of this type of antennas is circular. The gain of the antenna is generally low (see Fig. 5) which is a benefit, because the antenna impractical to be rotated.

In contrast, the magnetic loop antenna is a shortened antenna and has sizes considerably smaller than the wavelength (Fig. 2). Its perimeter is typically smaller than 1/3 the wavelength. Magnetic loops have lower efficiency and this hampers their implementation as transmitting antennas, but due to their very small sizes transmitting application are quite common.

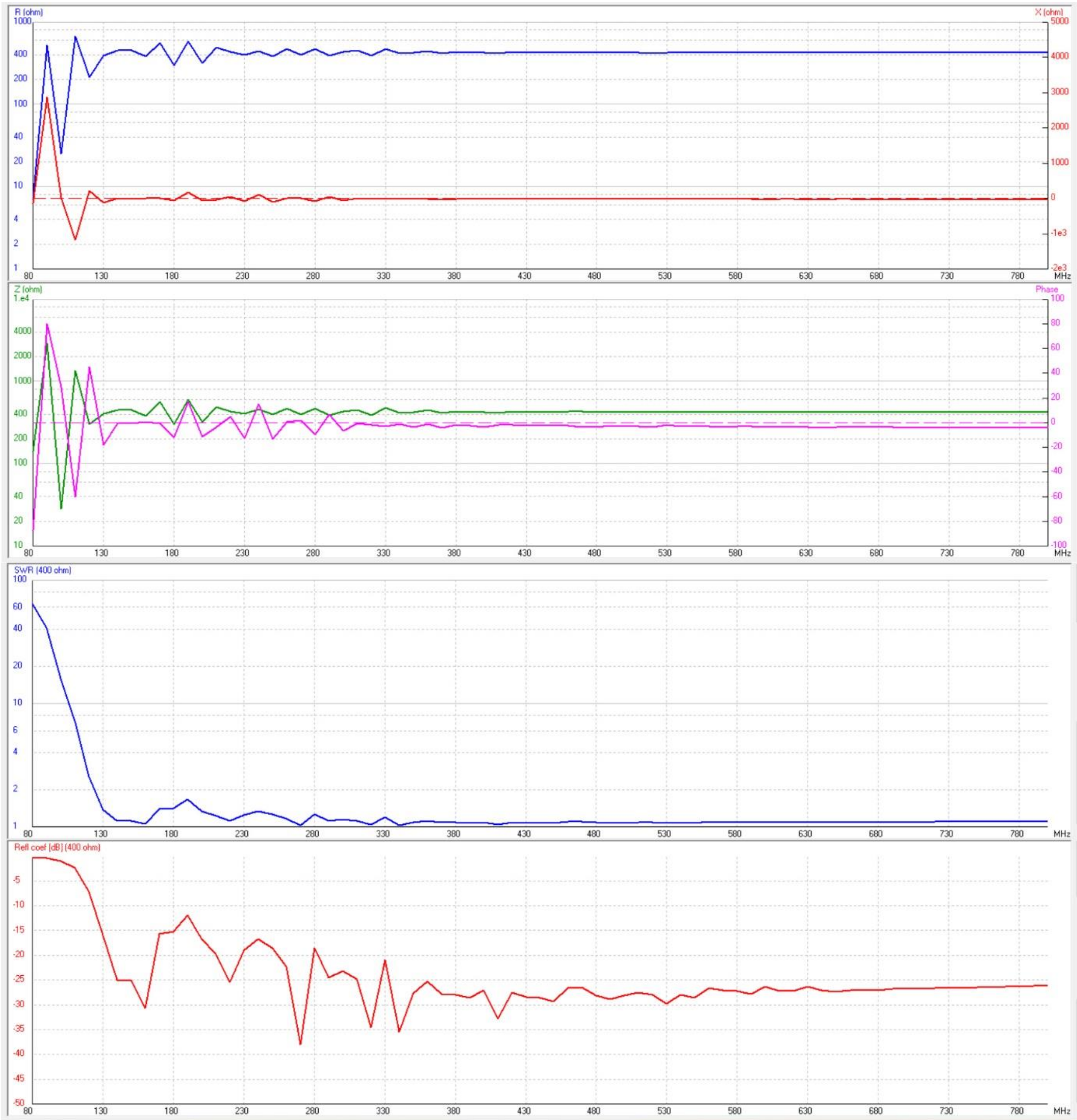


Fig. 3. Spiral antenna impedance and standing ware ration in respect to frequency

When employed as receiving antennas they may be electronically tuned, because the energy stored in the antenna and the corresponding voltages at the tuning capacitor are small enough. This type of antenna may also use a reflector. The radiation pattern has a maximum in the plane of the loop. The antenna polarization is linear. Also, it has a very pronounced and deep nulls along the loop axis. The latter is a benefit utilized to block the direct wave of the transmitter of opportunity.

The radiation resistance (in ohms) of the magnetic loop antenna is small and is proportional to the square of the area of the loop:

(1) $$R_r = 3.12 \times 10^4 \left(\frac{NA}{\lambda^2}\right)$$

Here A is the loop area in $m^2$, λ is the wavelength in m, and N is the number of turns of the loop conductor [11].

The efficiency of the magnetic loop is far from optimal and this is a drawback of this antenna type in comparison to the spiral antenna [12].

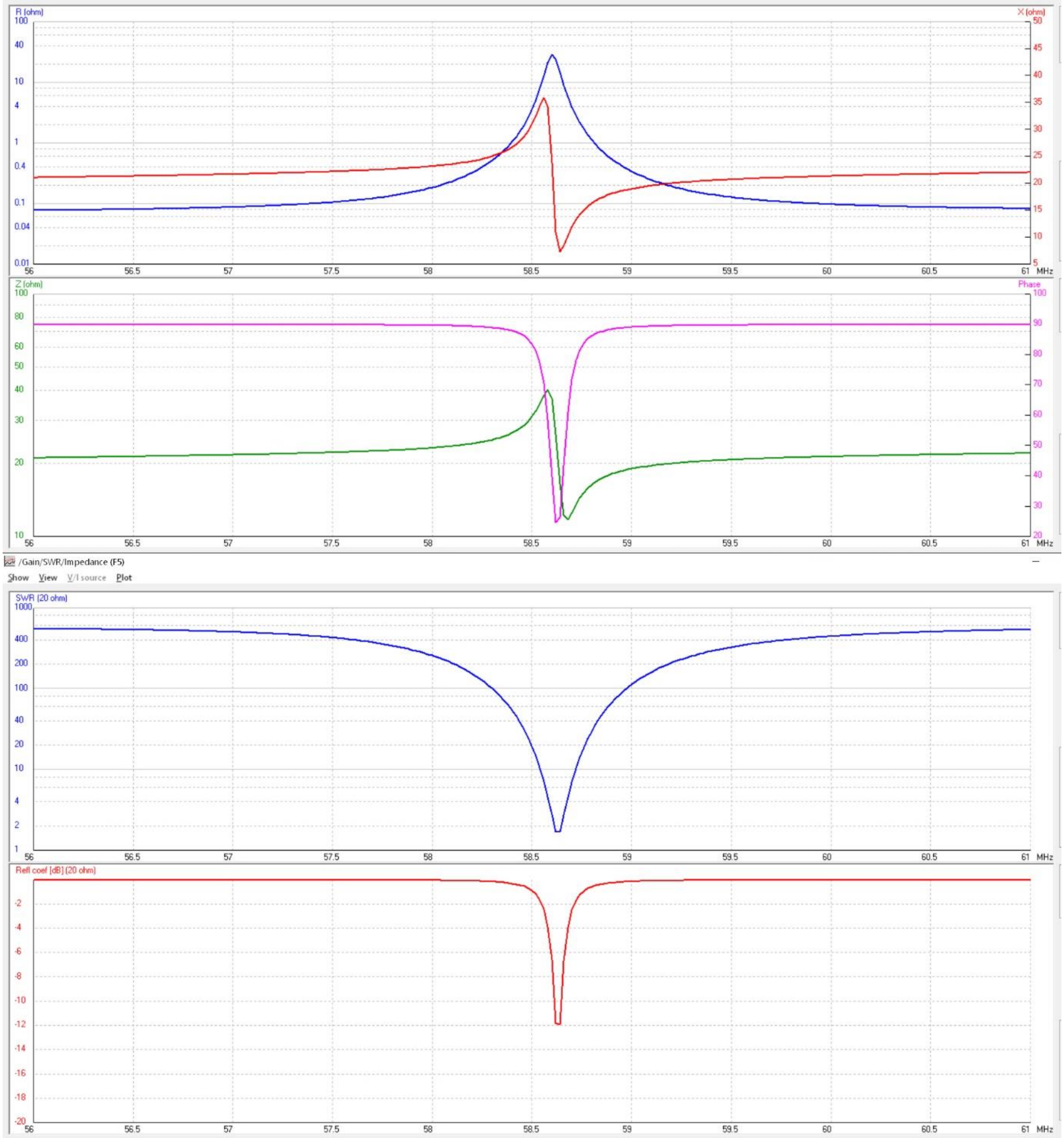


Fig. 4. Magnetic loop antenna impedance and standing ware ration in respect to frequency

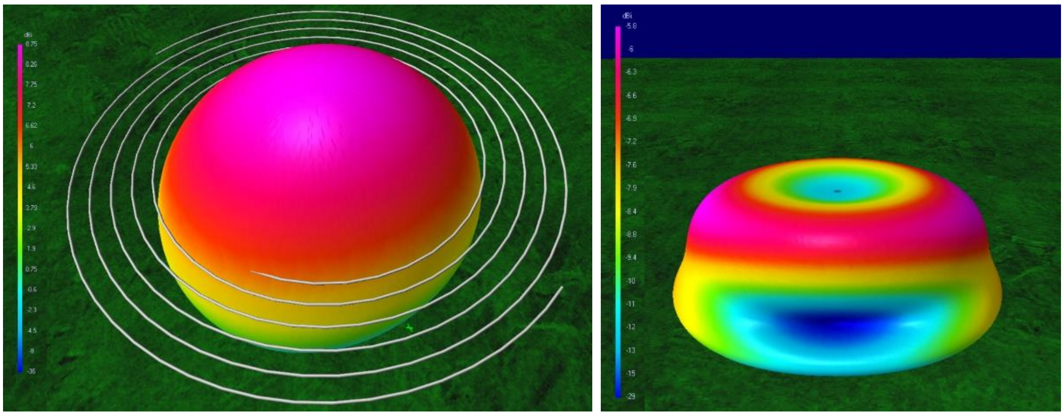

Fig. 5. Radiation pattern of the spiral antenna (left) and magnetic loop antenna (right). Both antennas are simulated above a ground plane.

Through numerical simulations and calculations at the band of interest [12-15] a 17.5 cm diameter loop will ensure 10 times more powerful received background noise than the receiver internal noise (10 dB). These figures are achieved by employing a 0.55 dB noise figure preamplifier (40 K noise floor) and having that the quiet rural noise is below the cosmic noise at 100 MHz. At that frequency the cosmic noise is around 6 dB above thermal background noise. The cited antenna diameter will provide an antenna with 3 dB attenuation or 50% efficiency which is within the boundaries of the receiver sensitivity.

## Conclusion

Both antenna types satisfy the established requirements. There are considerable differences when employing either of them.

The spiral antenna provides a wideband reception and enables the system to receive the reflected signal from several transmitters of opportunity simultaneously. It has the drawback of not isolating well the direct signal and having a wideband property it may overload the receiver input.

The magnetic loop antenna is a narrowband hi quality factor antenna and acts as a preselector. It protects the receiver from overload. With the help of its deep null by articulating the antenna through servos the direct wave can be blocked. The drawback is that the magnetic loop can receive only one signal (frequency) at a time. By using electronic tuning very fast tuning procedure to different frequencies is possible, still the articulation is slower process.

Both antennas are rigid and hard to observer visually. The team at Space Research and Technology Institute – Bulgarian Academy of Sciences estimates that both antenna types are suitable for future experiments with passive radar systems and further evaluation of their qualities in experimental setups are due.

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