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COMPOUND PRESELECTOR FOR MULTISTATIC PASSIVE RADAR EMPLOYED IN REMOTE SENSING APPLICATIONS

Svetoslav Zabunov, Garo Mardirossian

Space Research and Technology Institute — Bulgarian Academy of Sciences

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Abstract

Passive radars and multistatic passive radars in particular are gaining increasing attention. It is due to their effectiveness in detecting, tracking and identifying targets.

Multistatic passive radars are used in remote sensing observations of the Earth's ionosphere, meteors, space junk, etc. Another application is the detection and tracking of manmade objects and vehicles in the atmosphere or on the surface of the Earth.

The current paper discusses a hardware design approach applicable to the front-end of a multistatic passive radar receiver, namely a compound preselector. The preselector is a very important part of the radio receiver in cases where there are strong neighbouring signals in the radio band of operation. Such strong signals may overload the receiver or the low noise preamplifier and render the whole system dysfunctional. This article elaborates on a two-component preselector having very high rejection ratio to nearby emitters, still keeping the receiver simple and reliable.

The authors have registered several utility models on innovations in multistatic passive radars at Patent Office of Republic of Bulgaria.

Introduction

The multistatic passive radar is a type of a passive radar that employs more than one receiving antennas and/or more than one non-cooperative transmitters. The broader term “passive radar” on the other hand is a radar that relies on so called non-cooperating radio transmitters and does not have transmitters as part of its system [1]. The non-cooperative transmitters are transmitters that are maintained by other parties unknowingly of their use in the passive radar system. Such transmitters are also called transmitters of opportunity. Examples of non-cooperative radio transmitters are the FM/digital commercial broadcasting transmitters, communication networks base stations, etc.

Multistatic passive radars are implemented at tasks similar to other types of radars (Fig. 1). Nevertheless, their installation and maintenance costs are much lower [2]. Examples of passive radar applications are detection, ranging, identification and tracking of objects having radio frequency reflection properties. Such objects may be of anthropogenic origin, such as airplanes, Earth surface vehicles, spacecraft, space junk or they may be naturally occurring objects such as meteors, aurora, the Earth's ionosphere, etc.

Lately, an elevated interest in the scientific community has been established towards passive radars as means of remote sensing instruments. Exploring near Earth space and its phenomena is possible using passive radars. Interest has been shown in observing meteors, space junk and the ionosphere of our planet.

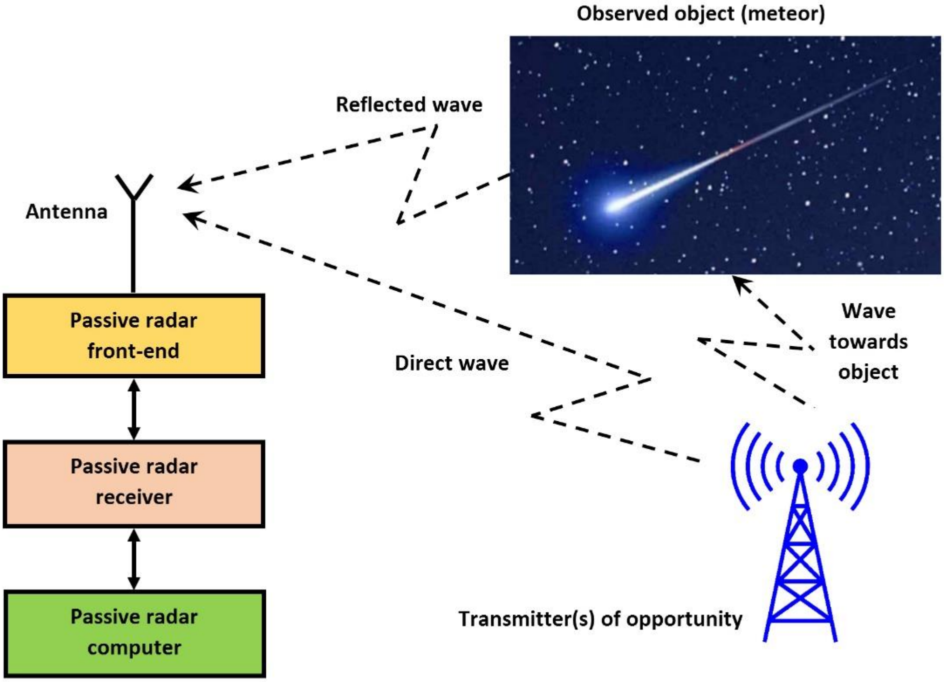

Fig. 1. Multistatic passive radar employing a compound preselector

There are plenty of transmitters of opportunity available for these purposes [3]. Some examples include the FM radio commercial broadcasting network [4, 5]. Other variant is the Digital Video Broadcast, either the terrestrial one (DVB-T) or the satellite based one (DVB-S) [6]. Another option is employing the cellular phone base stations. Still another possibility is to utilize the GPS signals and their reflections.

In Bulgaria, where the development of the proposed radar takes place, there are still functioning FM broadcasting transmitter not only located in the state's territory but also in neighbouring countries. Due to their low frequency of transmission FM broadcasting transmitters tend to be preferable transmitters of opportunity for such targets as the ionosphere [7–9], where higher frequencies would render the observed object radio wave transparent.

Compound preselector design

A passive radar system, as already mentioned, does not involve the installation and maintenance of its own radio transmitters. The only apparatus such a system encompasses is a radio receiver or a multitude thereof. The receiver may employ only one antenna (single channel) or several channels. After receiving and digitizing the signal the receiver feeds it to a computer where computation takes place [10]. Passive radar needs to compare the direct signal coming from the transmitter of opportunity and the reflected signal coming as a reflection from the observed object [11].

The simplest possible receiver would employ a single antenna/channel and will be using this single channel for receiving both signals. Such a design is rather inefficient because it would need a very high dynamic range receiver and the computation needed for separation of the two signals will be very complex and with unsatisfactory results and quality. To avoid these drawbacks a general rule with passive radar designs is to implement at least two antennas. One of the channels is involved in reception of the direct signal and the other one – for listening to the reflected signal(s). By positioning the two antennas separated in space from each other and by employing directional antennas the system will obtain good separation between the two signals. Most multistatic passive radar systems employ three or more channels to benefit from optimal positioning of the antennas in respect to different transmitters of opportunity or possible directions of the incoming reflected signals.

Every radio receiver is prone to overloading on its input. When a very strong signal is present incident to the antenna a high voltage is induced in the antenna feed and enters the receiver. This situation may have two aspects:

1. The unwanted strong signal is out-of-band, i.e. its frequency is not very close to the receiving frequency and is essentially out of the band of reception. In this case the parasitic signal needs to be very strong to penetrate the input filter of the receiver. When this happens the receiver input shall be overloaded rendering the receiver non-functional.
2. The parasitic signal’s frequency is close to the frequency of reception. This is called an in-band interference. The input filter of the receiver would admit the unwanted signal entering the receiver’s input non-attenuated. Thus, the parasitic signal may either overload the input of the receiver easily, or lead to distortion and leaking into the received signal and degrade the reception.

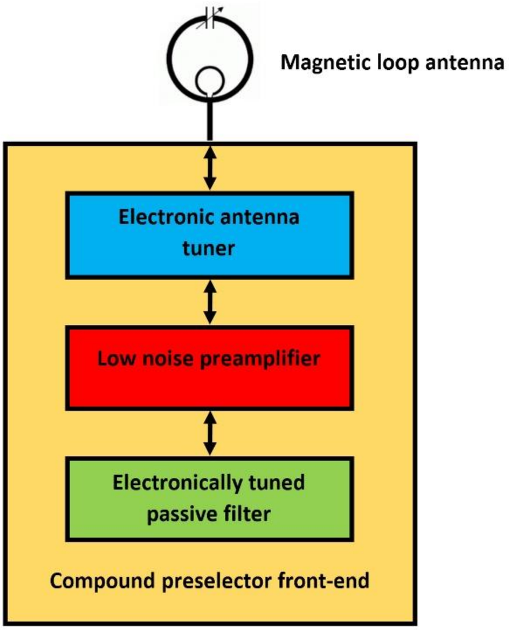

Fig. 2. Multistatic passive radar front-end consisting of a magnetic loop antenna, a two-stage preselector and a low noise preamplifier

In both cases a preselector should be used to attenuate the unwanted signal or signals to levels harmless for the normal operation of the receiver (Fig. 2). In the case of multistatic passive radars the operation is often taking place in bands where the transmitters of opportunity have strong signals. These signals are inherently in-band signals. They are capable of easily interfering with the reception. For this purpose, a sophisticated preselector is required [12, 13]. Such a preselector must also be simple to manufacture and operate and must have high efficiency and low noise. A way to achieve such a goal is to use a compound preselector consisting of two stages, the first stage of which is the antenna itself. Employing a high-Q factor antenna that is dynamically tuned will provide adequate efficiency and high selectivity. The tuning of the antenna must be electronic to achieve fast retuning and reliability. The filtered signal is then fed to a low noise preamplifier. Further, the signal enters the second stage of the preselector – an electronically tuned band-pass filter – where it is filtered again. The band-pass filter may consist of several components. The minimum filter order should be 4. The higher the order, the better the filtering, at the cost of increased complexity and cost. Such a receiver front-end guarantees very high dynamic range, extremely good rejection of unwanted signals that are in very close proximity by frequency to the received signal, low noise, low cost for manufacturing and maintenance, and high reliability.

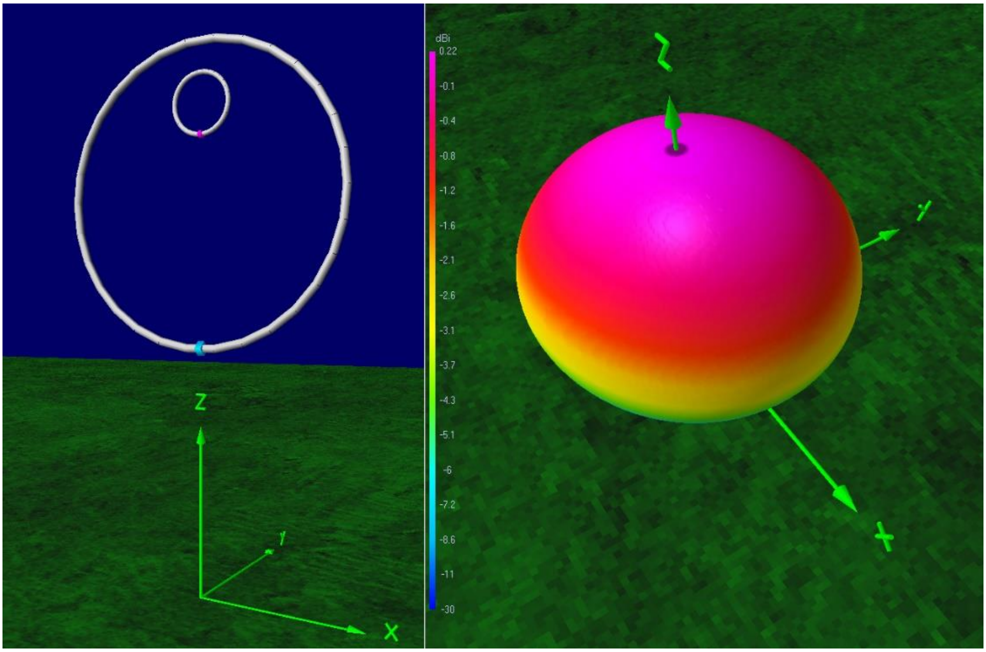

Fig. 3. Magnetic loop antenna represents the first stage of the compound preselector

Employing a magnetic loop antenna as a high-Q antenna that is easy to tune electronically is a good idea [14, 15]. This antenna has a number of benefits for the purpose of the multistatic passive radar such as deep nulls in its gain pattern, small size, preselector properties, easy to articulate using servos, small wind resistance, hard to spot by visual inspection, etc. The antenna was simulated using 4NEC2 free software for numerical antenna simulations. Some of the results in visual form are presented in Fig. 3 – the geometric electrical construction along with the antenna reception pattern is shown in the figure.

The principle electric schematic with only the essential components disclosed is presented in Fig. 4. The signal travels from left to right. The first component is the antenna shown as an inductor L-ANT. This inductor is tuned in resonance using electronic tuning component – varicap D1. Then the signal is amplified through a low noise preamplifier. After the preamplifier it is fed to a band-pass filter. This filter is also electronically tuned through the means of varicaps. Different orders for the filer are applicable. For clarity, Fig. 4 shows a 4th order band-pass filter consisting of two inductors L1 and L2 and two varicaps D2 and D3. Blocking capacitors are utilized to separate different stages of the circuit in regard to lower frequencies and the zero-frequency component. The varicaps are controlled by means of isolation resistors that have low capacity and high resistance.

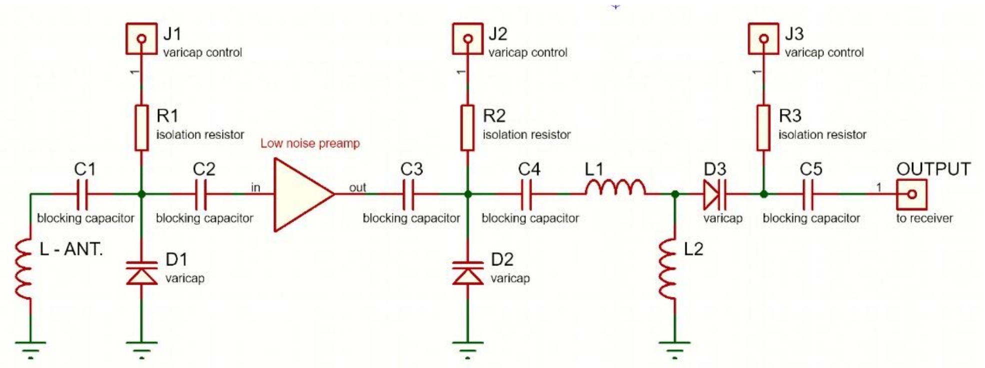

Fig. 4. Compound preselector principle electronic schematic

Conclusions

Multistatic passive radars are a fast-growing field of technological innovation and scientific research. Being appropriate for scientific observations in remote sensing applications, our team at the Space Research and Technology Institute – Bulgarian Academy of Sciences, has been profoundly involved in during the recent years. The Institute already has several registered utility models on different innovation aspects of multistatic passive radars [16–19].

Our future invention horizon aims at improvements in the hardware, novel approaches, and algorithms in the software, testing of modern supercomputing hardware for the purpose of computations, developing self-contained field-deployed base stations, improving the communications between base stations and data collecting servers, development, and design of antenna systems, etc.

Another field of work concerning multistatic passive radars in our Institute is their application in remote sensing observations of the Erath’s ionosphere, especially from the location of our country Bulgaria, due to the fact the in our territory to our disposal we can utilize a large number of Bulgarian and foreign transmitters of opportunity. This fact follows from our country being relatively small with many neighbouring countries that haven’t yet abandoned the FM radio broadcasting band.

References

1. Howland, P. E. “A Passive Metric Radar Using the Transmitters of Opportunity,” *Int. Conf.on Radar*, Paris, France, May 1994, 251–256.
2. Carson, S., Kilfoyle D., Potter M. and Vance J. "A passive, multi-static radar system," *2007 IET International Conference on Radar Systems*, Edinburgh, UK, 2007, pp. 1–4, doi: 10.1049/cp:20070497.
3. RADIO SPECTRUM DISTRIBUTION PLAN, Communications Regulation Commission, Republic of Bulgaria, 2019, https://crc.bg/files/_bg/647.pdf

4. Malanowski, M., Kulpa K. S., Kulpa J., Samczynski P., Misiurewicz J. "Analysis of the detection range of FM-based passive radar," *IET Radar, Sonar & Navigation*, Volume 8, Issue 2, February 2014, p. 153–159, DOI: 10.1049/iet-rsn.2013.0185.
5. Howland, P. E., Maksimiuk D., Reitsma G. "FM radio based bistatic radar," *Radar, Sonar and Navigation*, IEE Proceedings, Vol. 152, Issue 3, 3 June 2005, pp. 107–115.
6. Brisken, S., Moscadelli M., Seidel V. and Schwark C., "Passive radar imaging using DVB-S2," *2017 IEEE Radar Conference (RadarConf)*, Seattle, WA, 2017, pp. 0552-0556, doi: 10.1109/RADAR.2017.7944264.
7. Lind, F. D., Erickson P. J., Coster A. J., Foster J. C., Marchese J. R., Berkowitz Z., Sahr J. D. "Intercepted signals for ionospheric science," *Radio Science*, vol. 48, pp. 248–264.
8. Chernogor, L. F., Garmash K. P., Guo Q., Rozumenko V. T., Zheng Y. "Passive Radar for Oblique-Incidence Ionospheric Sounding: Observations of Ionospheric Storms," *2020 IEEE Ukrainian Microwave Week (UkrMW)*, Kharkiv, Ukraine, 2020, pp. 253–258.
9. Sahr, J. D., Gidner D. M., Chucai Zhou, Lind F. D. "Passive VHF radar for ionospheric physics," *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 63, issues 2–3, 2001, pp. 117–122.
10. Pölönen, K. "Signal Processing Methods for Multicarrier Passive Radar and Communication Systems," *Doctoral dissertation 69/2016*, Alto University publication series, 13.May.2016.
11. Meyer, M. G., Sahr J. D. "Passive coherent scatter radar interferometer implementation, observations, and analysis," *Radio Science*, vol. 39, RS3008, pp. 1–10.
12. Garry, J. L., Baker C. J. and Smith G. E. "Evaluation of Direct Signal Suppression for Passive Radar," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 55, no. 7, pp. 3786–3799, July 2017, doi: 10.1109/TGRS.2017.2680321.
13. Cutsogeorge, G. *"Managing Interstation Interference with Coaxial Stubs and Filters (2nd ed.),"* Aptos, CA: International Radio Corporation. P. 75.
14. Kraus, J. *"Antennas 2nd Ed,"* MacGraw Hill, 1988.
15. Carr, J. J. *"Practical Antenna Handbook, fourth ed.,"* McGraw-Hill, p. 625.
16. Zabunov, S., Mardirossian G., Nedkov R. "Recent Innovations in Circularly Polarized Antennas for Drone Radio Communication," *Comptes rendus de l'Acade'mie bulgare des Sciences*, 2020, vol. 73, no. 9, pp. 1286–1290.
17. Zabunov, S., Mardirossian G., Nedkov R. "MULTISTATIC PASSIVE RADAR," *Patent Office of Republic of Bulgaria*, 2020, https://portal.bpo.bg, utility model #3928/29.10.2020
18. Zabunov, S., Mardirossian G., Getsov P., Jelev G. "INTERNET-OF-THINGS STATIONS SYSTEM FOR PASSIVE RADAR," *Patent Office of Republic of Bulgaria*, https://portal.bpo.bg, 2022, utility model #4279/08.07.2022
19. Zabunov, S., Mardirossian G., Getsov P., Jelev G, Vasev V. "MULTISTATIC PASSIVE RADAR WITH MAGNETIC LOOP ANTENNA," *Patent Office of Republic of Bulgaria*, 2022, https://portal.bpo.bg, utility model #4337/25.10.2022

СЪСТАВЕН ПРЕСЕЛЕКТОР ЗА МУЛТИСТАТИЧЕН ПАСИВЕН РАДАР ЗА ДИСТАНЦИОННИ ИЗСЛЕДВАНИЯ

С. Забунов, Г. Мардиросян

Резюме

Мултистатичните пасивни радари се използват за дистанционни изследвания на земната йоносфера, следене на метеори, космически боклук и др. Друго приложение е при откриване и следене на антропогенни обекти и средства, които летят в атмосферата, Космоса или се намират на повърхността на Земята.

Настоящата статия дискутира подход при хардуерната конструкция на входното звено на мултистатичен пасивен радар, а именно преселекторът. Той се явява много важна част от радиоприемника в случаите, когато са налични силни сигнали с близка до приеманата честота в радиообхвата, в който се извършват наблюденията. Такива силни и близки по честота сигнали могат да пренатоварят (наситят) приемника и/или ниско шумовия предусилвател. Такова пренасищане би довело до неработоспособност на приемника, а оттам и на цялата радарна система. Публикацията обсъжда идеята за преселектор, състоящ се от две звена, който има много високо отношение на желание към нежелания радиосигнал. Нежеланият сигнал се намира в честотно измерение много близо до желания. Предложеното решение запазва ниска степен на сложност на хардуерната конструкция на приемника и така гарантира висока надеждност на работа и ниска цена за изработка и настройка.