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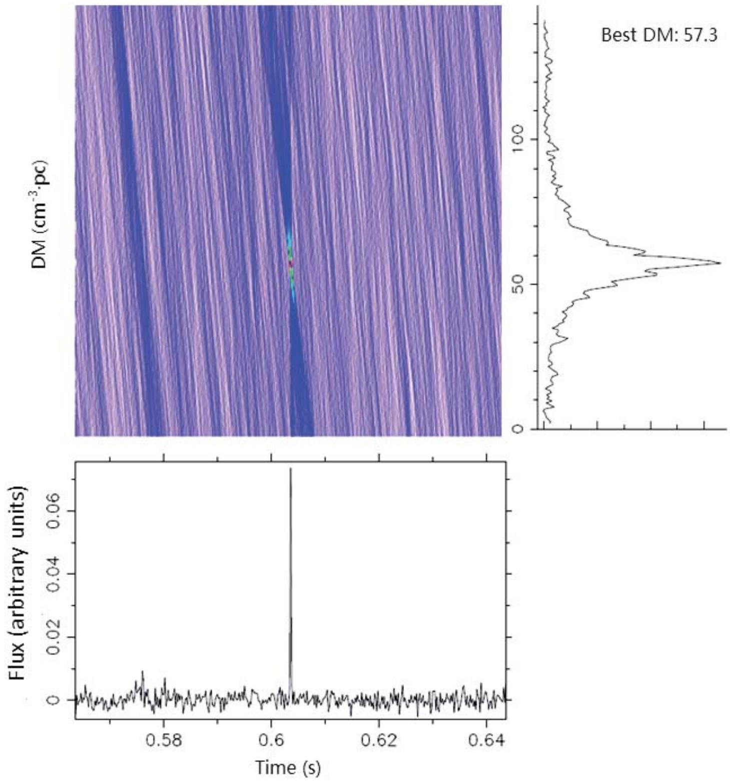

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Contents

Cover: The burst (giant pulse) hunting result obtained with the fast-radio-burst searching system for the Tian Ma Radio Telescope: time versus trial dispersion measures color-scale image of corresponding power (top left); time-averaged power curve versus trial dispersion measures (top right); the profile of the burst candidate obtained with the best-fitted dispersion measure (bottom). The top and bottom plots are shown with the same time axis. The left and right plots share the same dispersion-measure axis. See the paper by Zhen Yan, Zhi-Qiang Shen, Ya-Jun Wu, Rong-Bing Zhao, Ru-Shuang Zhao, Jie Liu, Zhi-PengHuang, Qing-Hui Liu, and Xin-Ji Wu.(pp. 10-18)

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Our Paper

The Shanghai Tian Ma Radio Telescope (TMRT) is a new radio telescope with impressive specifications. It has a fully steerable Cassegrain antenna with a diameter of 65 m. The antenna has an active surface, and the system is designed to operate from 1.2 GHz to 50 GHz. In their paper in this issue, Zhen Yan, Zhi-Qiang Shen, Ya-Jun Wu, Rong-Bing Zhao, Ru-Shuang Zhao, Jie Liu, Zhi-Peng Huang, Qing-Hui Liu, and Xin-Ji Wu describe the current and planned research projects related to pulsars for the TMRT. The paper begins with a review of pulsars and their characteristics. The TMRT pulsar observation systems are then described, including the receiver system and the quite special digital backend system. The signal processing associated with pulsar observations is explained. The TMRT pulsar observation projects are reviewed, with examples of results obtained being given. This includes long-term pulsar timing research, a search for high-frequency pulsars, investigations into pulsar radiation mechanisms, and the development of a real-time fast-radio-burst searching system for the TMRT. The use of the TMRT for pulsar observations using VLBI are described. The paper concludes with a look at prospective future projects for this new instrument. I think you'll find this a most interesting and readable introduction to the TMRT and to pulsar radio-astronomy observations.

Our Other Contributions

Be sure to take a look at Tayfun Akgül's commentary on what happens when Mother Nature gets tired of selfies, in his Et Cetera column.

Do you ever other-think trying to solve a problem? You should read what Randy Haupt and Amy Shockley have to say about "analysis paralysis" in their Ethically Speaking column.

Aşkın Altınoklu and Özgür Ergül have provided an interesting set of problems involving the use of arrays of nanoparticles as structures for providing enhanced directivity to radiation from a Hertzian dipole in Özgür's Solution Box column. Problem SOLBOX-13 looks at optimizing such arrays for directivity in different directions at a frequency of 200 THz when the particles are of different shapes and when different particles in the array are kept or removed. The computational challenges of such problems are significant.

In his Telecommunications Health and Safety column, James Lin looks at studies relating exposure to electromagnetic emanations from mobile phones to scores on memory-performance tests in adolescents. The results are fascinating, and raise some important questions.

Asta Pellinen-Wannberg has brought us the Women in Radio Science column in the Radio Science Bulletin for three years. In her column in this issue, she reflects on that experience, and shares some of what she has learned from those three years. She also shares some of the accomplishments that resulted from the column, and some possible future directions.

Make Your URSI AP-RASC 2019 Hotel Reservation Now!

The URSI Asia-Pacific Radio Science Conference (AP-RASC 2019) will be held March 9-15, 2019, in New Delhi, India. Information is available at http://aprasc2019.com/, including the ability to register for the conference and links to the recommended hotels. I urge you to make your hotel reservations now: room blocks at the hotels nearest the conference venue are filling up. Note that there is a substantial registration discount for Individual URSI Members. If you're not an Individual URSI Member, you can find out about membership at http://www.ursi.org/membership.php. There is no cost to become an Individual URSI Member, although you do have to qualify.

Over 952 papers were submitted from 40 countries to AP-RASC 2019. This is going to be an excellent conference. This is one of URSI's three flagship conferences: You should make your plans now to attend. Please note my comments in the last issue of the *Radio Science Bulletin* regarding the advisability of applying for a visa well in advance if you need one to attend.

Best Wishes!

As I am writing this, the holidays are upon us and the new year is almost here. My very best wishes to our whole URSI family for most joyous holidays, and for a very happy, healthy, safe, and prosperous New Year!

Ross

Pulsar Research with the Newly Built Shanghai Tian Ma Radio Telescope

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Abstract

The Shanghai Tian Ma Radio Telescope (TMRT) is a newly built fully steerable antenna with a diameter of 65 m. The frequency coverage of the TMRT ranges from 1.2 GHz to 50 GHz. Benefiting from its low-noise receivers and active surface, the sensitivity of the TMRT is very high, especially at relatively high frequencies. The digital backend system built at the TMRT well supports both the online folding and searching pulsar-observation modes. Meanwhile, the dispersion effect of the interstellar medium suffered by pulsar signals can also be removed with either the coherent or incoherent de-dispersion method, according to the demands of observers. A series of pulsar-related research projects have been arranged at the TMRT, such as long-term timing, high-frequency searching, radiation-process studying, and transient hunting. Most of these projects take advantage of the TMRT's high sensitivity at the corresponding frequency and try to avoid its disadvantages. More and more interesting pulsar research results with the TMRT are expected, based on the results obtained so far.

1. Introduction

A pulsar is a highly magnetized fast-rotating compact star (radius ~ 10 km) that emits lighthouse-like beams of electromagnetic radiation from its magnetic poles. Its radiation can be detected only when the beam of emission sweeps across the Earth. Since the first pulsar was discovered in 1967 [1] it was chosen as one of the important research targets of astrophysics. Because of its extremely strong gravitational, electronic, and magnetic fields, a pulsar is a very good space laboratory, testing the basic laws of physics in extreme conditions [2]. Compared with other celestial objects, a pulsar is a point source that has some special radiation properties, such as a narrow pulse, a high degree of polarization, and a relative stable inertial flux density. As its radiation passes through the interstellar medium before reaching the Earth, a pulsar shows obvious interstellar scintillation, scattering, and Faraday rotation, which makes it a unique probe for studying the interstellar medium [3, 4]. In addition, a pulsar timing array is an important tool for detecting low-frequency gravitational waves [5]. Besides the important usage for exploring basic physical laws, pulsar studies also have many practical applications. The extreme stability of millisecond pulsars allows them to be used in establishing ephemeris time [6]. Furthermore, a millisecond pulsar is a potential lighthouse with which to do deep-space spacecraft navigation [7].

There are about 2750 pulsars that have been discovered so far. More than 90% of them can only be detected in the radio bands. Without a doubt, radio observation is a very useful tool for pulsar research. Normally, the strength of the pulsar signal is extremely weak. It is indicated by the statistics of the S1400 (the flux density measured at 1.4 GHz) of currently known pulsars that the median value of S1400 is only 0.4 mJy, with a range between 0.01 mJy to 1100 mJy [8, 9]. A large antenna, with a diameter of tens of meters, and a highly sensitive receiver system, are needed to detect such a weak signal. Even with a very sensitive observation system, the individual pulse is only detectable on some strong pulsars. Most pulsars require the coherent addition together of thousands of pulses – a process called folding – in order to produce an integrated pulse profile that is discernible.

Beside the sensitivity problems, pulsar observations in the radio band have to face many other challenges, such as dispersion effects, high time resolution, and huge data rates. The Shanghai Tian Ma Radio Telescope (TMRT) is a newly built fully steerable Cassegrain antenna with a diameter of 65 m. Pulsars were chosen as one of the important scientific targets of the TMRT. In the following parts of this paper, we are going to give an introduction to the pulsar observations systems of the TMRT, presenting the testing observation results for some pulsars, and prospective pulsar-research work.

2. Pulsar Observation Systems of the TMRT

2.1 The Receiver System of the TMRT

The onsite construction of the TMRT (funded in 2008) mainly consisted of two epochs. In the first epoch of construction (2010-2013), most of the works arranged were mainly concerned with making the TMRT work well at four low-frequency bands. In the following epoch of construction (2013-2017), we devoted most of the time to building and testing the high-frequency observation system. The frequency coverage of the TMRT ranges from 1.2 GHz to 50 GHz, with eight sets of cryogenic receivers. The active surface system of the TMRT is also successfully put into work to compensate for gravitational deformations and to maintain the observational efficiency at high frequencies. The parameters of the receiving system are listed in Table 1 [10]. They are, respectively, the frequency range (FR), bandwidth (BW), system temperature (T_{sys}), aperture efficiency (η), system equivalent flux density ($SEFD$), and structure and polarization information. The $SEFD$ can be expressed as

$$SEFD = 2k\frac{T_{sys}}{A_e},$$

where k is the Boltzmann constant, T_{sys}, is the system temperature, and A_e is the effective area of the antenna. Since the $SEFD$ folds in both T_{sys} and A_e, it is a useful way to compare the sensitivity of two different systems.

Table 1. The receiver specifications for the TMRT.

Band		FR (GHz)	BW (GHz)	T_{sys} (K)	η	$SEFD$ (Jy)	Structure	Polarization
L		1.25-1.75	0.5	26	55%	39	Single Pixel	Dual Circ
S/X	S	2.2-2.3	0.1	33	60%	46	Dual Band	Dual Circ
	X	8.2-9.0	0.8	32	55%	48		
C		4.0-8.0	4.0	20	65%	26	Single Pixel	Dual Circ
Ku		12.0-18.0	6.0	22	62%	30	Single Pixel	Dual Circ
K		18.0-26.5	8.5	40	55%	61	Dual Pixel	Dual Circ
X/Ka	X	8.0-9.0	1.0	40	55%	61	Dual Band	Dual Circ
	Ka	30.0-34.0	4.0	56	53%	88		
Q		35.0-50.0	15.0	74	53%	116	Dual Pixel	Dual Circ

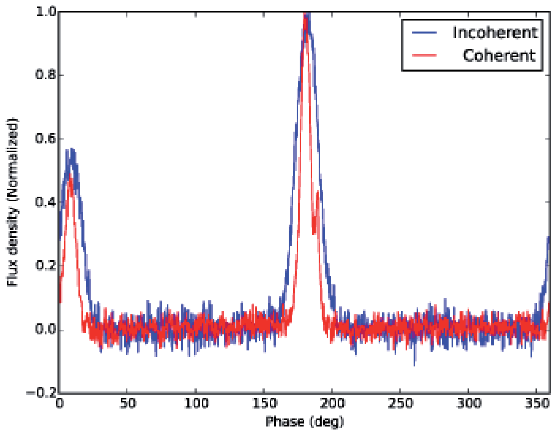

Figure 1. The average profile of PSR B1937+21 obtained with the coherent and incoherent online folding observation mode of the digital backend system.

At C band, the *SEFD* of the TMRT is about 26 Jy. For the Effelesberg 100 m telescope, the *SEFD* values of its C-band receiver, located at the prime focus and the secondary focus, are 18 Jy and 24 Jy, respectively [11, 12]. At higher frequencies, TMRT will receive more benefits in sensitivity from its active surface and low-noise receivers [13]. Judged from these parameters, it is clear that the TMRT is a high-sensitivity radio telescope, especially at C band frequencies and above.

2.2 The Digital Backend of the TMRT

Besides the high-sensitivity receiving systems, a special backend is needed to do high-quality pulsar observations. The backend needs to meet certain requirements, such as de-dispersion, wide bandwidth and high time resolution. The digital backend system (DIBAS) – which is an FPGA (field-programmable gate array) based spectrometer based upon the design of VEGAS (Versatile GBT Astronomical Spectrometer) with pulsar modes that offer much the same capabilities as GUPPI (Green Bank Ultimate Pulsar Processing Instrument) [14] – was built for data sampling and recording at the TMRT.

The digital backend system consists of three pairs of analog-to-digital converters (ADCs) and a Roach2 board, which can work in parallel or separately. The highest speed of the ADC is 5 Gsps (gigabits samples per second). The digital backend system supports both the incoherent and the coherent de-dispersion pulsar observation modes. The incoherent de-dispersion is a very computationally inexpensive technique that works by shifting the different channels in a channelized data set. However, the internal time delay in each channel cannot be eliminated by this technique. By comparison, the coherent de-dispersion technique is able to completely eliminate the effects of dispersive smearing by a series of deconvolution calculations. The coherent de-dispersion technique is much more computationally expensive. Unlike the incoherent de-dispersion processing done with the Roach2 units, the coherent de-dispersion operations are accomplished by the NVIDIA GPU (graphics processing unit) on eight high-performance computers connected to Roach2 units with the 10 Gbe switch. The digital backend system supports both the pulsar timing (online folding) and searching observation modes.

Overall, the digital backend system supports four principal pulsar observation modes: coherent de-dispersion pulsar search; coherent de-dispersion online folding; incoherent de-dispersion pulsar search; and incoherent de-dispersion online folding. For the incoherent de-dispersion observation mode, the maximum bandwidth supported by the digital backend system is mainly limited by the speed of the ADC. As the digital backend system consists of three pairs of parallel-operating ADCs and a Roach2 board, it can support a total bandwidth as high as 6 GHz in the incoherent de-dispersion observation mode. For the coherent de-dispersion observation mode, the maximum bandwidth supported by the digital backend system is 1 GHz, which is limited by the computation capability of the GPUs. The highest time resolution of the digital backend system is at the level of 40.96 microsecond, meaning it can give suitable time resolution to do millisecond pulsar observations. A parallel file system, called *Lustre*, is used to meet the demand of storing the huge rate of data in the high time resolution observation. The highest data-recording rate of our Lustre file system storage is about 300 MB/s per thread. The observation data is written out in PSRFITS format, meaning it can be easily processed by normally used pulsar software [15].

A series of tests on the digital backend system was arranged before it came into real use. In Figure 1, we present an example of the test results on the millisecond pulsar PSR B1937+21, obtained with the incoherent and coherent de-dispersion online folding observation modes of the digital backend system at L band. PSR B1937+21 is a pulsar with the shortest rotational period in the northern sky (P~1.56 ms). The DM (dispersion measure) of this pulsar is 71.02 $cm^{-3}pc$ and the S1400 is 13.2 mJy [8, 9]. The total bandwidth of the L-band receiver was "channelized" and divided into 1024 channels for both observations. The length of each observation was 10 min. Theoretically speaking, the coherent de-dispersion technique should remove the dispersion effects more thoroughly than the incoherent de-dispersion. The plots in Figure 1 show the results that we expected. The pulses shown in Figure 1 were integrated profiles that were obtained by summing tens of thousands of single pulses. Although the highest time resolution of the data sampling was 40.90 μs, it was possible to sample different phases of a series of a single pulse, as the period of the target pulsar was not an integer times the sampling time. When we summed these single pulses up, it was possible to obtain an integrated profile that seemed to be of higher time resolution. Compared with the result obtained with the incoherent de-dispersion mode,

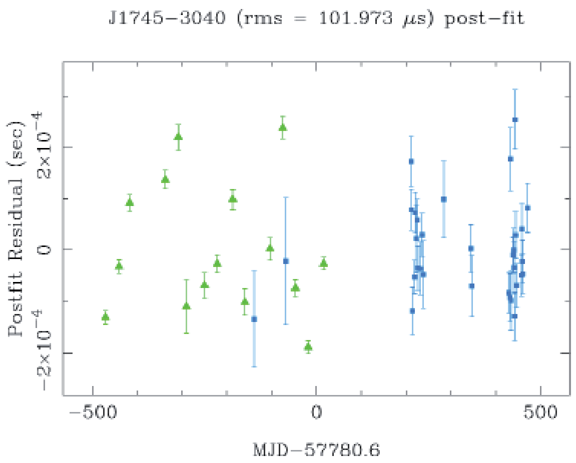

Figure 2. Timing results for PSR J1745-3040 obtained with Parks (L band, green) and TMRT (S band, blue)

much finer structure of the average profile was obtained with the coherent de-dispersion observation mode. The sub-peak of the main pulse, which could not be detected in the incoherent de-dispersion observation mode, was detected in the coherent de-dispersion observation mode. After a series of test observations, we could draw the conclusion that the digital backend system was a well-working pulsar observation backend.

3. Pulsar Observation Projects and Some Related Results

From the information presented above, it is clear that the TMRT is a high-sensitivity antenna that has been equipped with well-working pulsar observation backend. By comparison, the TMRT is less affected by RFI (radio-frequency interference) at the relatively high-frequency bands (C band and above). Some pulsar observation projects are being carried out to make full use of its high sensitivity and avoid its disadvantages.

3.1 Long-Term Pulsar Timing

Pulsar timing is the regular monitoring of the time of arrival (TOA) of the radio pulses. Pulsar timing allows the astronomer to study the rotation evolution of the pulsar [16], to probe its inertial structure [17], to make accurate astrometry measurements [18], to test General Relativity theories, and so on [19, 20]. As with most other large-diameter radio telescopes, long-term pulsar timing was also chosen to be one of the important regular observation projects at the TMRT. Considering the RFI state and the power-law spectrum of pulsars, S band was chosen as the normally used frequency for doing pulsar-timing observations at the TMRT. It was indicated by testing

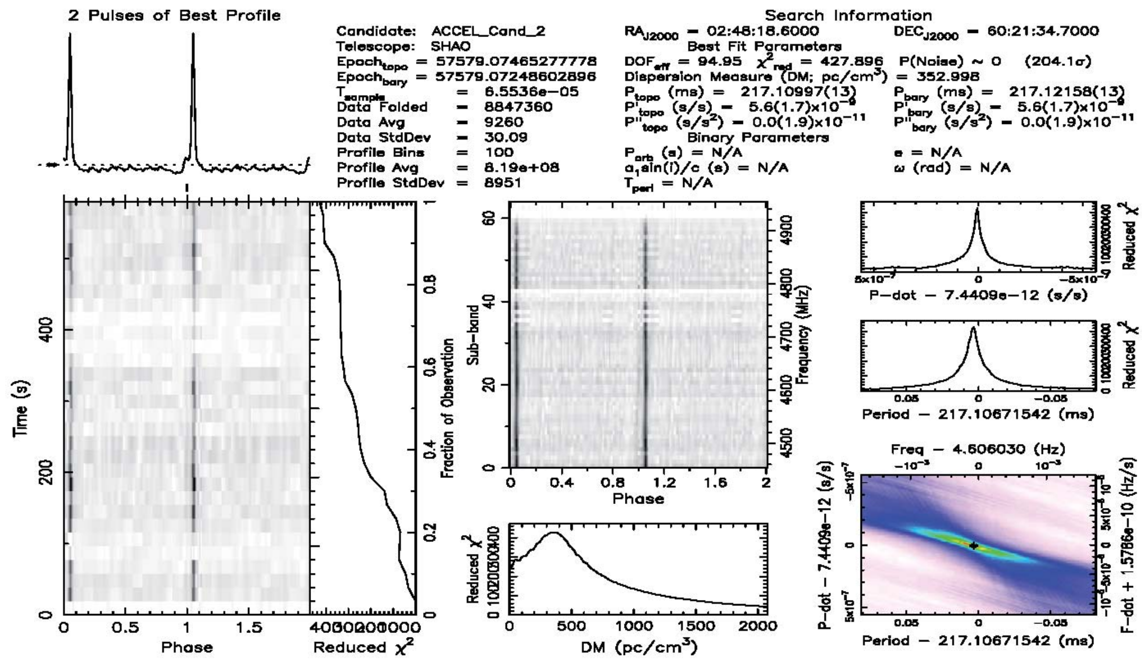

Figure 3. Blind search results for PSR B0248+6021 with scripts based on *PRESTO*. Left panel: The summed pulse profile (top), the time versus phase grayscale image of power (bottom); Center panel: the frequency versus phase grayscale image of power (top), the dispersion measure (DM) versus RCS (bottom); Right panel: the slow down rate (p-dot) versus RCS plot (top); the period versus RCS plot (middle); the p versus p-dot color-scale image of RCS. In the grayscale image, the darker structure corresponds to the strong power. In the color-scale image, as the color varies smoothly from blue through cyan and yellow, to red, the RCS get larger and larger.

observations that the TMRT has the ability to monitor the time properties of about 350 pulsars at S band, including 10-millisecond pulsars. Compared with other low-frequency observations, the pulsar-timing observations at S band will be affected by comparatively lower flux density of pulsars because of their power-law spectrum. On the other side, higher frequencies will be less affected by the interstellar medium, especially the variation in long-term dispersion measures.

In pulsar timing, timing residuals are the differences between the observed times of arrival and the predictions from the timing model. We can improve the accuracy of the model as more pulsar data becomes available. The post-fit timing residuals effectively measure how well the updated timing model describes the data. In order to check that the long-term stability of the TMRT pulsar observation system is suitable to do pulsar timing, we tried to do timing analysis on the observational data obtained with the TMRT (S band) and the Parkes (L band).The post-fit timing residuals of PSR J1745-3040 are shown in Figure 2. The S1400 of this pulsar is about 21 mJy [8, 9]. The typical integration time of the observation data obtained with the TMRT was 10 min, and it was about 3 min with the Parkes. The observational sensitivity of the TMRT on this pulsar was affected by the limited bandwidth and its lower flux density at S band. From the scatter range of the timing results shown in Figure 2, we inferred that the long-term stability of the TMRT makes it possible to do further pulsar-timing observations.

3.2 High-Frequency Pulsar Search

Although there have been about 2750 pulsars discovered, this is only the tip of the iceberg. It is predicted by simulation that there are about 30000 pulsars that can potentially be detected among the total 150000 pulsars in the Milky Way [21]. Finding new pulsars, especially the exotic systems, will give better understanding about both the evolution and related physics of pulsars. Pulsar searching has also been chosen as one of the important pulsar research projects at the TMRT. If the pulsar search is carried out at low frequencies with the TRMT, there will be some disadvantages to be faced, such as comparatively serious RFI and no multi-beam (or phased-array) receivers. To avoid these disadvantages and take advantage of its high sensitivity at relatively high frequencies, the pulsar search will be carried out at comparatively higher frequencies, such as C band and X band. On the other hand, we could not do large-area sweeping pulsar searching as can other large telescopes with multi-beam (or phased-array) receivers. We are doing deep searches at the Galactic center and some globular clusters. It is inferred that there are up to 100 normal pulsars and 1000 millisecond pulsars in the inner parsec of the Milky Way Galaxy [22], but none of them have been discovered except for the magnetar J1745-2900. It will therefore be quite meaningful work if more pulsars can be discovered in this area.

We have now written some automatic pulsar-search pipelines based on *PRESTO* [23]. These pipelines were tested by doing a blind search (assuming we had no idea of the real period and dispersion-measure values) of the observational data of some known pulsars. In Figure 3, we present an example of the blind-search results for the large dispersion-measure pulsar J0248+6021. The reduced chi-squared (RCS) subplot shows how much the data do or do not look like noise. When the reduced chi-squared is 1, it means that the data look exactly like noise. The higher the RCS becomes, the less it looks like noise. According to what is shown in Figure 3, obvious peaks were detected at $\mathrm{DM} \sim 353\ \mathrm{pc/cm}^{-3}$ in the dispersion measure versus RCS plot and at $P \sim 217\ \mathrm{ms}$ in the period versus RCS plot. These results were equal to the corresponding true parameters of this pulsar within the error range. This pulsar was thus successfully re-discovered.

3.3 Pulsar Radiation Mechanisms

The pulsar radiation process is still an open field. The shape of a single pulse can be seen as the photograph of the magnetosphere at the time the pulse was emitted [24]. For a certain pulsar, its individual pulses are often consistent with several characteristic sub-pulses with typical widths of 1° to 3°, which are much narrower than the average pulse profile (with a typical width of 10°). Although individual pulse shapes vary considerably, the shape of the average profile is quite stable. The average profile can thus be thought of as a “fingerprint” of the emission beam [25]. However, some pulsars exhibit mode changing, where the average profile switches between two or more quasi-stable modes of emission [26]. Observations of average pulse profiles and their polarization give us macro-information on the shape of pulsar beams. On the other hand, single-pulse observation provides information about pulsar radiation from micro views. Some observations indicate that there are some potential relations between phenomena shown on single pulses and average profiles [27]. Furthermore, different frequencies of signals originate from different locations of the magnetosphere [28]. Multi-frequency observation results on the single and average pulse profiles will give very valuable information about pulsar radiation mechanisms from different dimensions. Meanwhile, it is helpful to reveal the potential connection between micro and macro phenomena of pulsar radiation, such as the sub-pulse drifting and the mode switching.

Some research work has been carried out by taking advantage of the high sensitivity of the TMRT (especially at relatively higher frequencies). Multi-epoch observations on PSR J1745-2900 at X band with the TMRT indicated that both the flux density and the average profile of this pulsar showed dramatic changes with time. Single-pulse analysis showed that the bright spiky pulses of this pulsar cannot be classified as giant pulses, because of their log-normal peak energy distribution and low total power [29].

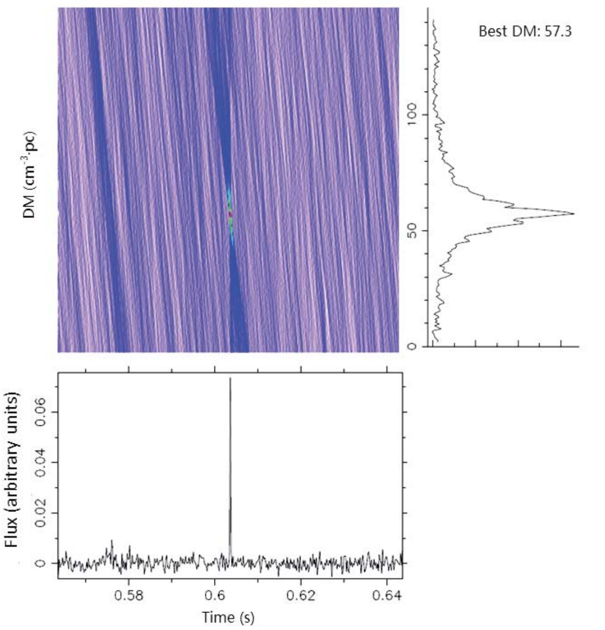

Figure 4. The burst (giant pulse) hunting result obtained with the fast-radio-burst searching system for the TMRT: time versus trial dispersion measures color-scale image of corresponding power (top left); time-averaged power curve versus trial dispersion measures (top right); the profile of the burst candidate obtained with the best-fitted dispersion measure (bottom). The top and bottom plots are shown with the same time axis. The left and right plots share the same dispersion-measure axis

By comparisons of five different fitting functions, it was found that the square hyperbolic secant function could best reproduce the multi-frequency profiles of PSR B1133+16. The radiation altitude and Lorentz factors of the particles were also calculated, based on multi-frequency profiles. It was found that the Lorentz factors of the particles decreased rapidly as the radiation altitude increased [30]. Multi-epoch simultaneous S-band and X-band single-pulse observations of PSR B0329+54 with the TMRT indicated that its sub-pulse drifting properties changed with the observation frequency and pulsar radiation mode [31].

3.4 Radio Transient Observation

Besides the classic pulsars, the transient radio sky has revealed many classes of exotic objects, such as the rotating radio transient (RRAT) and fast radio burst (FRB) [32, 33]. They are manifested as transient radio pulses lasting a few milliseconds, on average. Compared with the rotating radio transient, the repeating properties of the fast radio burst are still unknown. Until now, the repeating phenomena have only been detected in one fast radio burst, although there are more than twenty fast radio bursts that have been discovered [34]. Searching for fast radio bursts is an extremely time-consuming project. For a normal radio telescope, it will take at least hundreds of hours to have a chance to discover one case of a fast radio burst [35]. It is impossible to predict when and where the fast radio burst will come. If there is a real-time fast-radio-burst searching system that can work in parallel with other observations, it will take full use of the telescope's time. As the data that are judged as potential fast-radio-burst signals can only be recorded by the real-time fast-radio-burst searching system, the volume of data recording will effectively be minimized. On the other hand, follow-up monitoring for a fast radio burst can also be arranged if the fast radio burst could be detected in real time.

We are developing a real-time fast-radio-burst searching system for the TMRT. Considering the large dispersion-measure values of known fast radio bursts, it is reasonable to divide the total observation band into much smaller channels. For a normal observation with a setup such as 2048 channels and an 80 μs time resolution, the data rate is about 100 MB/s. In the process of a fast-radio-burst search, it is necessary to do a de-dispersion operation on data streams of tens of megabytes with hundreds of trial dispersion measures. A GPU (NVIDIA GeForce GTX 1080) with 2560 processing cores was used to meet the demand for intensive computation in the dispersion-measure search. We have now finished most of the work of developing such a fast-radio-burst searching system. We did a lot of offline tests on the Crab pulsar. The length of processing time is only about half of the data-recording time. In Figure 4, we present an example plot of a giant pulse from the Crab pulsar detected at S band with our fast-radio-burst searching system for the TMRT. To make the plots clear, we only showed the results corresponding the best-fitted dispersion measure, although the dispersion-measure search range was from 0 to $2000\ \mathrm{cm}^{-3}\mathrm{pc}$ in our tests. From the dispersion-measure curve and the pulse-profile plots, it was clear that the giant pulse from the Crab pulsar had been successfully detected with the best-fitted dispersion measure value of $57.3\ \mathrm{cm}^{-3}\mathrm{pc}$. We will do more online testing in the next steps to make this come into real use in the real-time fast-radio-burst search.

3.5 Pulsar Observations with the VLBI

As the related techniques quickly progress, it is possible to detect a series of pulsars with VLBI (very-long baseline interferometry). VLBI plays very important roles in pulsar research. Pulsar astrometry will give extremely accurate model-independent distance and proper-motion measurement results on pulsars, which are important for clarifying their association with supernova remnants, studying their evolution, building the Galactic electron model, and so on [36]. In order to study the extremely anisotropic interstellar scattering towards toPSR B0834+06, its scattered brightness was astrometrically mapped with VLBI at the level of 0.1 mas resolution [37].

As a member of the European VLBI Network (EVN), the TMRT has regularly participated in the normal section

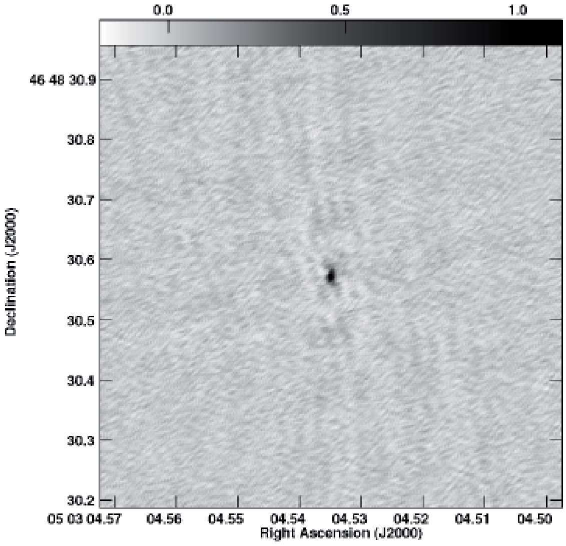

Figure 5. The image of PSR B0458+46 obtained with the VLBA plus the TMRT.

of EVN observations. Besides that, the TMRT also does VLBI observations with other antennas. We did a path-finding pulsar astrometry observation with VLBA at L band. The backends used for the TMRT was CDAS (Chinese VLBI Data Acquisition System) and for the VLBA, the PFB (PolyPhase Filterbank) was used. Compared with previous joint pulsar observations, the data-recording rate was upgraded from 512 Mbps to 2048 Mbps. The participation of TMRT lengthened the baseline two times in the east-west direction and substantially improved the UV-coverage of observation. The path-finding VLBI pulsar observation was successfully carried out after overcoming some technical problems. The image result of one target pulsar B0458+46 is shown in Figure 5. PSR B0458+46 is a normal pulsar of relative weak radiation. Its rotational period is 0.64 s and its S1400 flux density is 2.5 mJy [8, 9]. From the plots shown in Figure 5, it could be seen that PSR B0458+46 was successfully detected. There will be more pulsar astrometry projects to be arranged with the TMRT plus other telescopes.

4. Conclusions and Prospects

As discussed above, the pulsar is one of the important scientific targets at the TMRT. Pulsar observation systems that work well have been built at the TMRT. A series of pulsar research works have been arranged by now. Besides the work described above, the TMRT is ready to join more and more cooperative pulsar research projects with other telescopes all over the world. Following up of timing observations on some pulsar candidates discovered by the FAST (Five-hundred-meter Aperture Spherical radio Telescope) have been started at the TMRT. Recently, the TMRT also took part in the Global Crab campaign to contemporaneously observe the Crab over a wide range of frequencies, along with worldwide telescopes (such as LWA, Parkes, GBT, GMRT, and Arecibo). In the long run, we are considering joining the International Pulsar Timing Array (IPTA) to make some contributions to the direct detection of gravitational waves. More and more interesting research results with the TMRT are expected based on observation results obtained so far.

5. Acknowledgements

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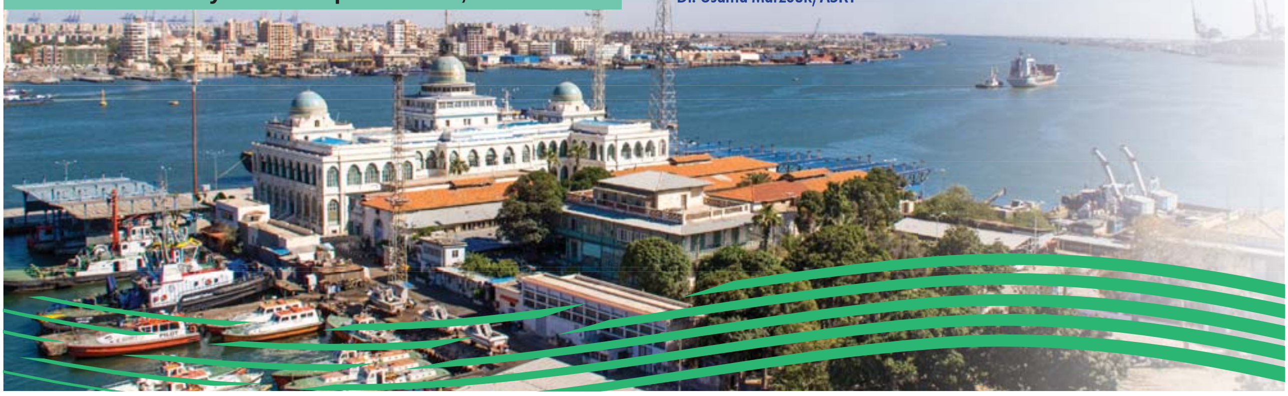

In Memoriam: Carl Henrik Walde

Chief Engineer Emeritus, former head of the Naval Telecom Bureau and the Joint Services Radio Bureau at the Swedish Defense Materiel Administration, Carl Henrik Walde, quietly passed away on June 18, 2018, at the age of 83 years. Left to cherish his memory are his wife Karin and their daughters, Kristina and Maria, with their families.

Calle (everybody who knew Carl Henrik well just called him Calle) was born in Gothenburg (Göteborg) in 1935. He graduated secondary school at Vimmerby, Sweden, in 1953. In 1958, he received his Master of Science in Engineering Physics at KTH, Royal Institute of Technology, in Stockholm. After graduation, he was employed by the Swedish Defence Materiel Administration (FMV). He was first a naval engineer, and later a non-combatant employee and head of the Radio Bureau at FMV.

In the early 1980s, Calle was appointed the representative for the FMV organization in the Swedish National Committee of Radio Science (SNRV). SNRV serves under the auspices of the Royal Swedish Academy of Sciences (KVA), and it represents Sweden in URSI. Calle continuously served in SNRV during 36 years. During the last 24 years he was its highly appreciated Secretary, until he resigned as honorary member of SNRV in 2017. Such a long engagement in SNRV is exceptional and unparalleled, and Calle's significance for the accomplishments of SNRV cannot be overestimated.

The list of Calle's important efforts in Swedish radio science is long and comprehensive. He was one of the founders of the Nordic Radio Society (NRS), which later was transformed into a foundation. NRS is a nonprofit Swedish organization with a general goal of maintaining radio scientific skills in the Nordic countries at an internationally high level. The society also acts as a forum for contacts and Nordic seminars in radio science.

Calle was the enthusiastic and natural chair of the international shortwave radio conferences, held biannually at Fårö, Sweden. He realized early the historical value of the long-wave radio station at Grimeton on the Swedish west coast. This pre-electronic radio station, SAQ, is now part of UNESCO's World Heritage (2004). Calle made a major contribution in establishing radio communication links to foreign locations. A particular example was the establishment of a radio communication link between Antarctica and Sweden for the Swedish Polar Research Secretariat.

Calle was a devoted radio amateur, under the key SM5BF [Silent Key], and played an important role as an honorary member at the Swedish Amateur Radio Society (SSA). Proof of his engagement in the SSA was his long record as Chair at the society's annual meetings, the last one in April 2018. Preserving the radio history of Sweden was close to Calle's heart. He made numerous efforts in saving old radio stations and preserving technical museums in Sweden for the future.

Calle was the obvious and natural leader of SNRV. During his time as Secretary of SNRV, he planned and organized all of our meetings. He was the driving force behind our Nordic collaboration, and we warmly remember his organization of the trips to our radio-science colleagues in Finland, Denmark, and Latvia, and to leading radio industries in Sweden. These two-day excursions vitalized SNRV both nationally and internationally. Several memorable events at KVA were pursued with Calle as coordinator, e.g., the celebration in 2006 of the 75th anniversary of SNRV, and the symposium in 2009 of the 100th anniversary of Marconi's and Braun's Nobel prize.

Calle was indispensable for the work in SNRV, with his many contacts and his large personal network. He showed empathy, and he was a considerate colleague. The world has turned a bit grayer without Calle, a devoted radio amateur, a fantastic, unique, and energetic person, who made every meeting with SNRV pleasant. With the demise of Calle, Sweden lost a true enthusiast, and we who have been fortunate to interact with Calle deeply mourn him.

Gerhard Kristensson, Honorary Member and former Chair of SNRV
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IEEE RADIO 2019

IEEE RADIO 2019 CALL FOR PAPERS

IEEE Radio and Antenna Days of the Indian Ocean
23 – 26 September 2019, Reunion Island

IEEE

CALL FOR PAPERS

The **2019** edition of the **IEEE Radio and Antenna Days of the Indian Ocean (IEEE RADIO 2019)** will be held from **23rd to 26th September 2019** in **Reunion Island**. **IEEE RADIO 2019** is the 7th edition of a series of conferences organized in the Indian Ocean region. The aim of the conference is to discuss recent developments, theories and practical applications covering the whole scope of radio frequency engineering, including radio waves, antennas, propagation and electromagnetic compatibility.

Prospective authors are invited to submit original contributions on their latest research activities. Student papers are strongly encouraged. **IEEE RADIO 2019** will feature three **Best Student Paper Awards**, a **Young Scientist Award** and an **Industrial Engineering Paper Award**. Proposals for special sessions, workshops and tutorials are welcome. A panel of distinguished researchers will deliver keynote speeches/invited talks on recent technology trends and advances.

Topics of the conference

1. Antenna theory
2. Wave propagation and scattering
3. Electromagnetic compatibility
4. Analytical and numerical methods
5. Smart antennas and arrays
6. RF components and systems
7. Wireless communication systems
8. Biological effects
9. Wireless power transfer
10. Devices and circuits
11. Nanotechnology
12. Radio astronomy
13. Remote sensing
14. High-power devices and techniques
15. Instrumentation and measurement techniques
16. Medical and industrial applications of electromagnetic fields
17. Modeling, simulation, computer aided design
18. Electronic packaging and integration
19. Metamaterials and other novel materials
20. Any other relevant topic

Language and Venue

The **working language** will be **English**.
The conference will be held in **Reunion Island**.

Important information

Submission of 2-pages paper: 15th May 2019

Proposals for tutorials, special sessions, workshops: 30th May 2019

Contact: radio2019@radiosociety.org

Website: http://www.radiosociety.org/radio2019

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Even Mother Nature gets tired of selfies!

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Analysis Paralysis

Randy L. Haupt and Amy J. Shockley

My hair turned white a long time ago – and now, I'm starting to lose it. Many people blame these hair problems on stress, and I'm stressed! Look at all of the decisions that I have to make! For instance, Sue and I went to London last spring, and rather than packing food from home, we decided to eat out. Did you know that at last count, there are over 18,000 restaurants in London? How was I to pick where to eat? I could have starved to death before fully analyzing all of the possibilities. I gathered information from the hotel clerk and the Internet. I asked people for suggestions, which seemed to make the people on the elevator uncomfortable when I grilled them about restaurant possibilities. Of course, picking a restaurant was only part of the problem. Once you get to the restaurant, what do you order? I am so exhausted after making the decision on where to eat that I just ask the server for a recommendation. By the way, that usually works well.

Analysis paralysis, paradox of choice, or decision paralysis occurs when a person is confronted with too many decisions, or the decisions are so important that over-analysis of the data induces inaction. Paralysis connotes the inability to act or reach a solution. Many situations are interpreted as too complicated, causing decision makers to be paralyzed by the fear that the consequences of any given alternative could lead to an even larger problem. Perfectionists often fear errors caused by quick decision making, and instead default to waiting, in an attempt to gather more data in order to make the best decision possible. A survey found that working professionals worldwide are finding information overload to be a serious, growing problem that exacts a heavy toll in terms of productivity and employee morale [1]. Employees report spending 51% of their work time receiving and managing information, rather than using the information in their jobs. Introducing additional options increases decision difficulty, and often leads to choosing the most distinctive option or maintaining the status quo. In an example involving a patient with osteoarthritis, family physicians only prescribed a medication 53% of the time when deciding between two medications, verses 72% of the time when only considering one medication [2]. Apparently, the inability to decide between two treatments led some physicians to recommend not starting either. Over-thinking lowers your performance on mentally demanding tasks, kills your creativity, eats up your willpower, and makes you less happy [3].

In the big picture of life, deciding where and what to eat is pretty trivial. About a year ago, I had cataract surgery. Prior to the surgery, I had to choose between three types of artificial lenses to put in my eyes. The Level 1 lens would cost me nothing, but had the lowest performance. Level 2 had better performance and would cost me about US$1,000. In both cases, I was told that I would have to wear glasses for either reading or for seeing at a distance. The final choice was a multi-focal lens that could entirely eliminate my need for glasses, but at a cost of US$4,000. I debated. This was an important decision that I would have to live with for the rest of my life. I did not want to make the wrong choice. I ended up asking my ophthalmologist, "If you were deciding for yourself, which would you choose?" Without hesitation, he said that he would pick the most-expensive option. That was therefore what I did. I'm happy with my decision and no longer need glasses: a great result of the surgery. Did I make the right decision? I will never know. I cannot compare my choice with the other choices.

My brother got the same surgery four months later, and picked the cheapest alternative. He is also happy. In fact, he does not see halos around lights at night, as I now do. My doctor said that the halos go away for most people, but being skeptical, I did research. It turns out that my lenses are Fresnel lenses. I looked at my halos and counted the diffraction rings, and they correspond to the discontinuities in the lens' steps. They can't go away. They will always be there. I enlightened my ophthalmologist, and we decided that the halos go away for most people because they learn to ignore them.

A humorous solution to decision paralysis is Rangnekar's Modified Rules Concerning Decisions [4]:

1. If you must make a decision, delay it.

2. If you can authorize someone else to avoid a decision, do so.

3. If you can form a committee, have them avoid the decision.

4. If you can otherwise avoid a decision, avoid it immediately.

More serious approaches break the paralysis by:

- Looking at whether a decision meets your needs rather than maximizes your needs. If four out of 10 choices are satisfactory, then randomly selecting one of the four should make you happy, as long as you do not start second guessing. All of my lens decisions were better than living with cataracts.

- Asking other people with experience and expertise for opinions. Ophthalmologists and restaurant servers are good examples.

- Setting a decision deadline and sticking to it.

- Remembering that not making a decision is a decision.

In Aesop's fable, "The Fox and The Cat," a fox boasts to a cat that he has many tricks for evading hunters. The cat confesses to having only one way to avoid hunters. When the hunters actually show up, the cat climbs a tree, while the fox takes time to think through his many options. Unfortunately for the very smart fox, the hounds get to him before he can decide. Sometimes, any decision is better than no decision. More than likely, the cat ended up happier than the fox.

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13th International Congress on Artificial Materials for Novel Wave Phenomena

Metamaterials 2019

Rome, Italy, 16 – 21 September 2019

The *Thirteenth International Congress on Artificial Materials for Novel Wave Phenomena – Metamaterials 2019*, will comprise a **4-day Conference** (**16–19 September**), and a **2-day Doctoral School** (**20–21 September**). Organized by the *METAMORPHOSE VI AISBL* (www.metamorphose-vi.org), this Congress follows the success of *Metamaterials 2007-2018* and continues the traditions of the highly successful series of *International Conferences on Complex Media and Metamaterials* (*Bianisotropics*) and *Rome International Workshops on Metamaterials and Special Materials for Electromagnetic Applications and Telecommunications*. The Congress will provide a unique topical forum to share the latest results of the metamaterials research in Europe and worldwide. It will bring together the engineering, physics, applied mathematics and material science communities working on artificial materials and their applications in electromagnetism/optics, acoustics/mechanics, transport, and multi-physics.

Paper Submission

Papers should be 2-3 pages long and contain an abstract, a brief conclusion, and a main body where technical content and novelty of the work are clearly presented.
Papers should be submitted as camera-ready PDF files to the website:

http://congress2019.metamorphose-vi.org

Authors are requested to use the template provided on the Congress website when preparing their submission. Authors of accepted and presented papers will be given the option of publishing their work in IEEE Xplore subject to the manuscript compliance with the format and copyright requirements.

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Submission deadline

10 March 2019

Topics

We interpret metamaterials as rationally designed composites, the effective properties of which go beyond their bulk ingredients, qualitatively and/or quantitatively. **We accept papers in any combination out of the following 8 categories**:

Category 1 - Area
- Electromagnetic from DC to optical and beyond (including, e.g., metallic, dielectric, magnetic, and superconducting ingredients)
- Acoustic and mechanical (including, e.g., seismic)
- Transport (including, e.g., nanoelectronics, and thermal transport)
- Multi-physics

Category 2 - Geometry
- 1D, 2D, and 3D metamaterials and metasurfaces
- (1+1)D, (2+1)D, and (3+1)D space-time metamaterials and metasurfaces
- Individual meta-atoms
- Meta-systems (including, e.g., gradient metamaterials, metamaterials in architectures designed by coordinate transformations, as well as far-field and near-field imaging systems)

Category 3 - Arrangement
- Periodic
- Non-periodic

Category 4 - Frequency
- Static
- Dynamic (including wave propagation)

Category 5 - Type
- Passive
- Active

Category 6 - Status
- Fixed properties
- Tunable properties (including, e.g., modulators, switchable properties, software-defined, and adaptive properties)

Category 7 - Physical basis
- Classical (linear and nonlinear, including, e.g., multistable and programmable)
- Quantum

Category 8 - Technology Readiness Level
- Effective-medium theories and homogenization (including, e.g., high-frequency and high-contrast homogenization and spatial dispersion modelling)
- Design (including, e.g., analytical approaches, topology optimization, numerical methods, machine and deep learning, bio-inspiration)
- Fabrication and characterization (including, e.g., new manufacturing approaches, 3D additive manufacturing, parameter retrieval, reliability testing, and fatigue testing)
- Applications and commercialization (including, e.g., antennas, sensing, spectral and spatial filtering, civil engineering, marine engineering, biology, and earthquake protection)

In addition, we accept papers on composites, plasmonics, photonic crystals, phononic crystals, and invisibility cloaking if related to the scope of the congress in some way.

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SOLBOX-13

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1. Introduction

Nanoantennas, i.e., antennas with details/dimensions of the order of nanometers/micrometers, have become increasingly popular [1-8], hand in hand with the advances in nanoscale fabrication. Some of the well-known potential applications are energy harvesting, optical sensing, optical communication, and particle detection. Despite nanoantennas typically having less complicated geometries in comparison to their counterparts used at radio and microwave frequencies, they still need to be carefully designed in accordance with the purposes of the application [5, 7-9]. In fact, the strong plasmonic properties of metals at optical frequencies can make it challenging to control the radiation and scattering characteristics of nanoantennas and their arrays.

In SOLBOX-13, described in this issue, nanoantenna arrays are considered for achieving desired radiation characteristics at optical frequencies. As opposed to the one-dimensional arrays that were considered in SOLBOX-06 [9], two-dimensional arrangements of nanoparticles needed to be found. With the increased number of elements, finding optimal configurations became more challenging. Sample solutions that are also presented in this issue were obtained via genetic algorithms, supported by full-wave solutions using surface integral equations. The results demonstrated favorable radiation properties for the designed structures, while they also showed that the configurations found were not globally optimal. As an open problem, better configurations may therefore be found with alternative techniques that may be more suitable for this kind of design processes. The timing results also showed the need for acceleration.

With SOLBOX-13, we have now 13 different sets of computational problems with diverse properties and aims. *Do not keep alternative solutions to yourselves*: share them here to demonstrate potentially better ways to solve the problems described. Also, send your challenging problems to this column if you are seeking alternative solutions.

2. Problems

2.1 Problem SOLBOX-13 (by *Aşkın Altınoklu and Özgür Ergül*)

The problem SOLBOX-13 includes arrays of nanoparticles arranged periodically in a 9×9 grid. Five different particles, as well as a sample array of cubes, are

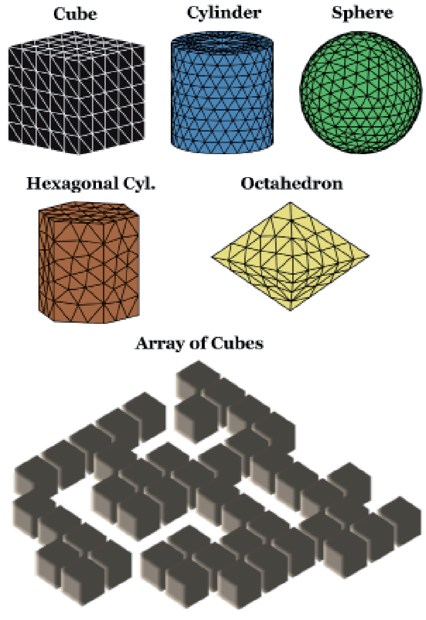

Figure 1. Nanoparticles to be used for constructing arrays and a sample array of cubes.

depicted in Figure 1. The edge length of the cubes was 0.75 μm, while the dimensions of other particles were selected accordingly such that they fit into 0.75 μm × 0.75 μm × 0.75 μm volumes. Considering that the arrays were located on the *x*-*y* plane, the periodicity in both the *x* and *y* directions was 0.9 μm. One Hertzian dipole in the *z* direction was located at the middle of the array (particle-free space), and a full array (without optimization) contained a total of 80 particles located symmetrically around it. The material of the particles was selected as Ag, while the arrays were assumed to be located in vacuum. The frequency was set to 200 THz, at which the frequency-domain relative permittivity of Ag is approximately $-96.0 + 75\mathrm{i}$, where i represents the imaginary unit. As shown in the sample solutions that are also presented in this issue, the aim was to optimize the overall structure by extracting selected particles such that the structure provided increased far-zone radiation (directivity) at desired directions in comparison to other directions. Specifically, the objective was to determine optimal configurations of kept/extracted particles. As the main results of optimization trials and simulations, radiation characteristics that demonstrated the effectiveness of the optimized structures, as well as the array configurations (kept particles), can be shown.

3. Solution to Problem SOLBOX-13

3.1 Solution Summary

Solver type (e.g., noncommercial, commercial):
Noncommercial research-based code developed at CEMMETU, Ankara, Turkey
Solution core algorithm or method:
Frequency-domain MLFMA + genetic algorithms

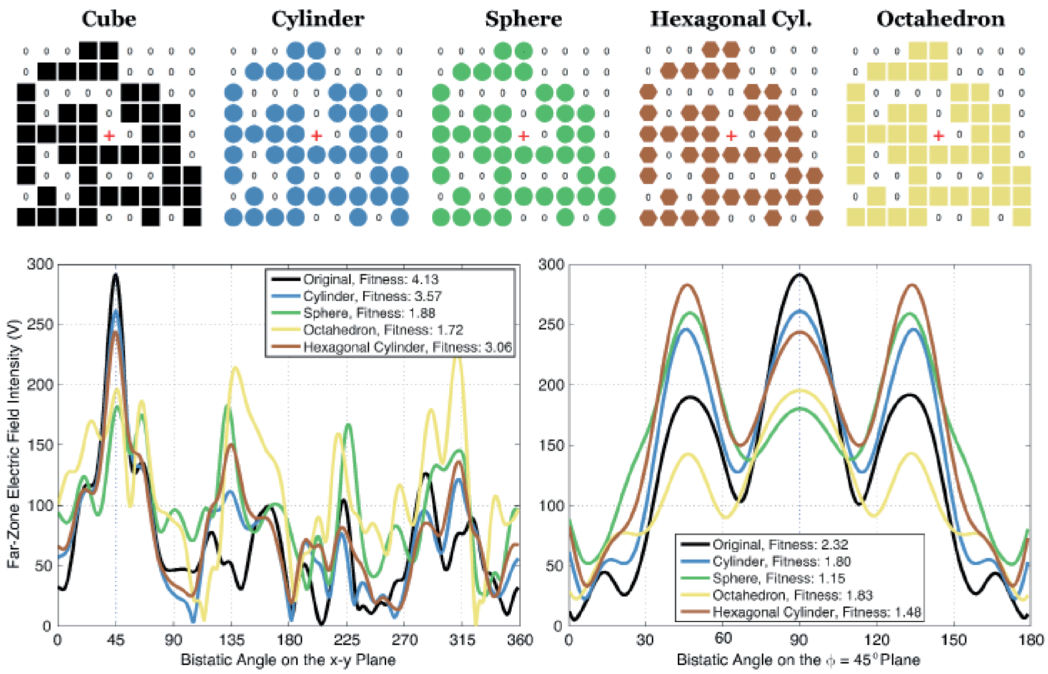

Figure 2. The results of an optimization (array configuration and far-zone electric-field intensity values) when the radiation was maximized at $\phi_0 = 45°$ using cubic particles. The radiation characteristics when using other types of particles in the optimized arrangement are also shown.

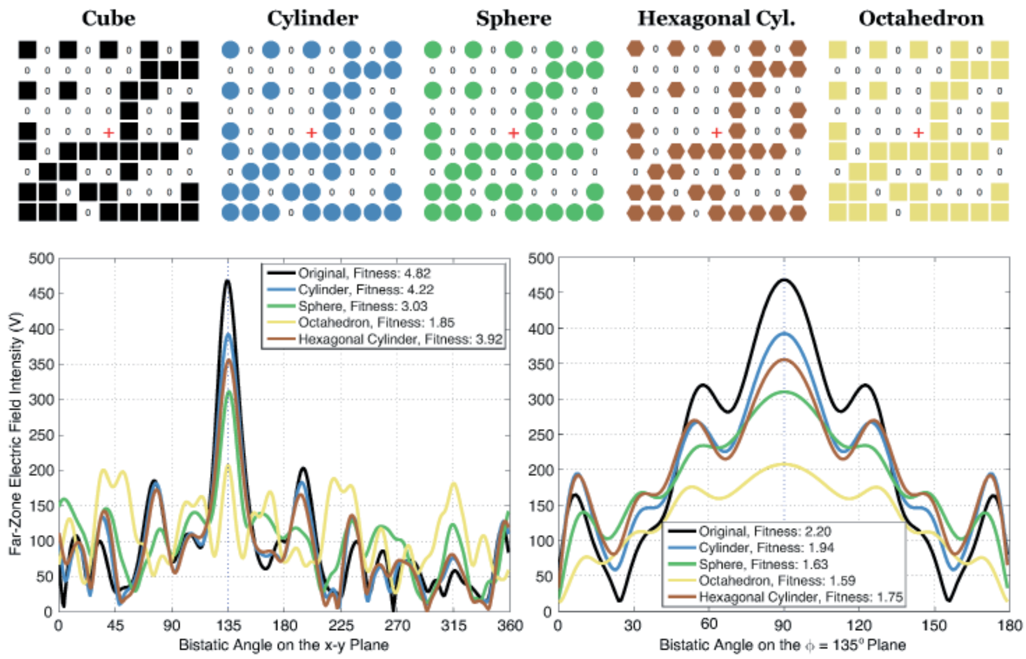

Figure 3. The results of an optimization (array configuration and far-zone electric-field intensity values) when the radiation was maximized at $\phi_0 = 135°$ using cubic particles. The radiation characteristics when using other types of particles in the optimized arrangement are also shown.

Programming language or environment (if applicable):
MATLAB + MEX

Computer properties and resources used:
2.5 GHz Intel Xeon E5-2680v3 processors (using 16 cores)

Total time required to produce the results shown (categories: <1 sec, <10 sec, <1 min, <10 min, <1 hour, <10 hours, <1 day, <10 days, >10 days): <1 day for each optimization

3.2 Short Description of the Numerical Solutions

The optimization problems described in SOLBOX-13 were solved by using a robust mechanism based on the Multilevel Fast Multipole Algorithm (MLFMA) [10] and genetic algorithms. Radiation patterns were optimized by maximizing the far-zone radiation at different directions on the *x-y* cut (array plane). For an optimization at an azimuth angle of ϕ_0, the cost function to be maximized was selected as $CF = CF_1 \times CF_2$, where CF_1 is the radiation in the optimization direction normalized with the mean value on the *x-y* plane, and CF_2 is the radiation in the optimization direction normalized with the mean value on the $\phi = \phi_0$ plane. The implementation of genetic algorithms involved improved optimization operations [11] and dynamic accuracy control [12]. Each optimization was performed by using pools of 40 individuals and a maximum of 100 generations, leading to a maximum of 4000 simulations per optimization. In the MLFMA solutions, the radiation problems were analyzed with the modified combined tangential formulation (MCTF) [13] discretized with the Rao-Wilton-Glisson functions. All interactions, if not truncated [14], were computed with a maximum 1% relative error, while the target residual for iterative convergence was set to 0.0001.

3.3 Results

In the following, a total of eight different optimization results are presented. First, using cubic particles, the far-zone radiation was maximized at $\phi_0 = 45°$, 135°, 225°, and 315°. For further comparisons, the radiation pattern was then also maximized at $\phi_0 = 45°$ using other types of particles. First, Figure 2 presents the optimization results when the radiation pattern was maximized at $\phi_0 = 45°$ using cubic particles. The arrangement of the kept cubic particles (black squares) is shown, where the Hertzian dipole was located at the middle. Once the optimal configuration was found via optimization, other particles were also directly used to investigate the effect of the particle geometry on radiation characteristics. Figure 2 includes the far-zone electric field intensity (V) in the *x-y* plane and on the $\phi_0 = 45°$ plane. The partial cost-function values, i.e., CF_1 and CF_2 as defined in the problem description, are indicated in the legends. We observed that using cubic particles, the radiation was maximized at the desired direction, $\phi_0 = 45°$. We noted that since the array was on the *x-y* plane, more oscillatory (and also controllable) radiation could be achieved on this

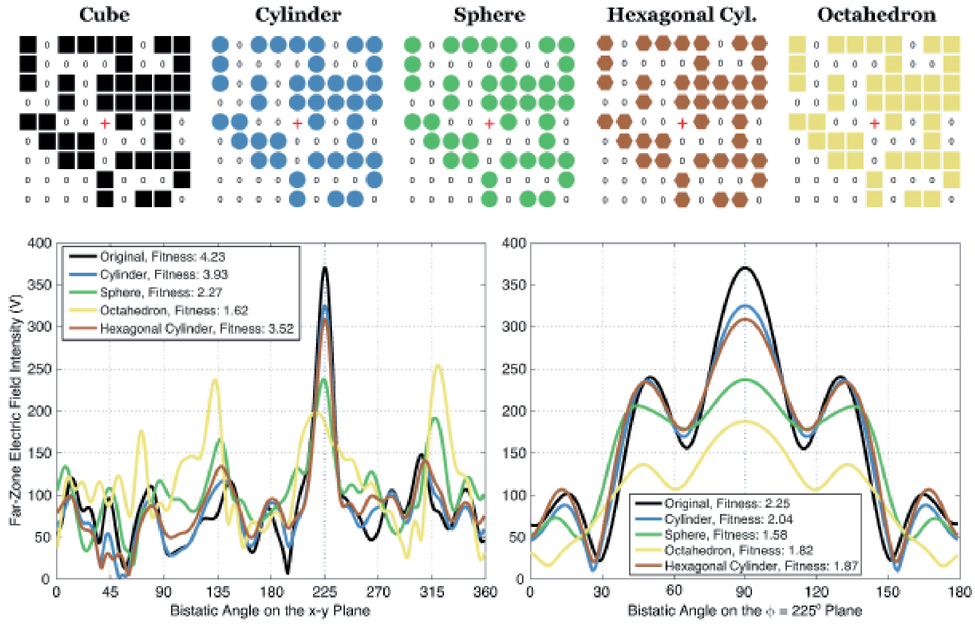

Figure 4. The results of an optimization (array configuration and far-zone electric-field intensity values) when the radiation was maximized at $\phi_0 = 225°$ using cubic particles. The radiation characteristics when using other types of particles in the optimized arrangement are also shown.

plane, while the radiation was smoother in the elevation plane. Using original (cubic) boxes, the partial cost-function values were approximately 4.13 and 2.32 on the planes considered, leading to $CF = CF_1 \times CF_2 \approx 9.58$. As expected, using other types of particles in the optimal configuration led to deteriorations in the performance of the array. For example, using spherical particles, we had only $CF \approx 1.88 \times 1.15 \approx 2.16$. One could observe that the electric-field intensity for this case was still high in the desired direction, while significant peaks also occurred in other directions. Using octahedral particles as the extreme case, the maximum radiation occurred in another direction on the x-y plane.

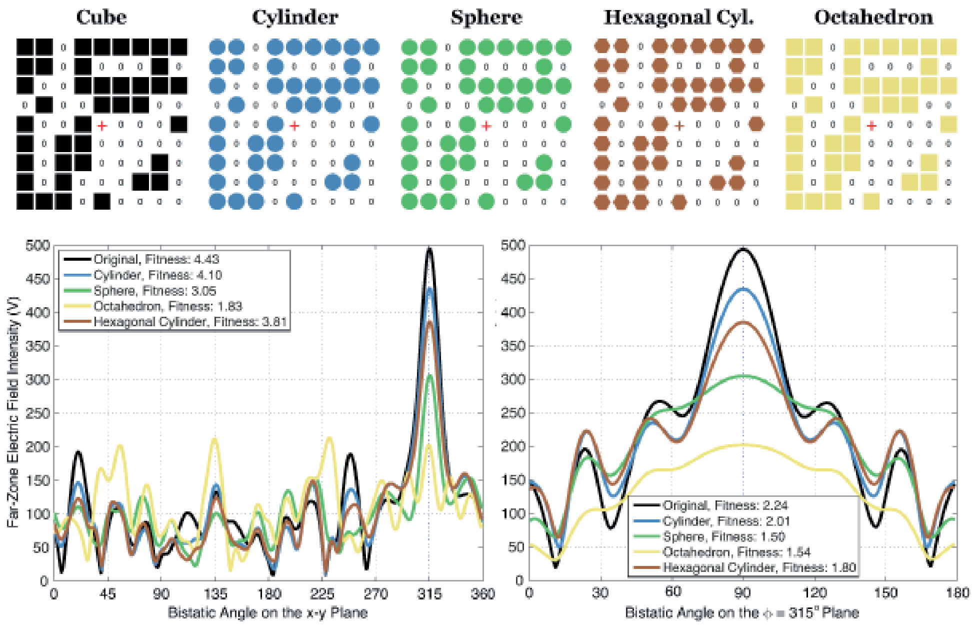

Figure 5. The results of an optimization (array configuration and far-zone electric-field intensity values) when the radiation was maximized at $\phi_0 = 315°$ using cubic particles. The radiation characteristics when using other types of particles in the optimized arrangement are also shown.

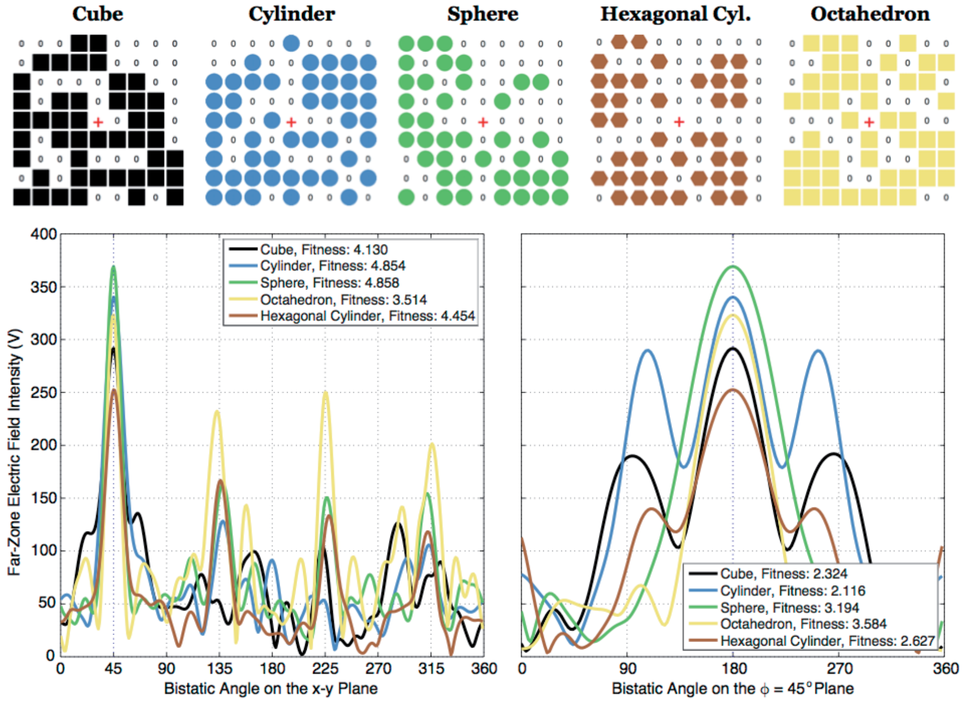

Figure 6. The results of optimization trials (array configurations and far-zone electric-field intensity values) when the radiation was maximized at $\phi_0 = 45°$ using various types of particles.

Figures 3, 4, and 5 present the results when the optimization direction was selected as $\phi_0 = 135°$, $\phi_0 = 225°$ and $\phi_0 = 315°$, respectively. The results were similar to those in Figure 2. Specifically, in each case the maximum occurred at the desired direction using cubic particles that were used in the optimization. The corresponding values for the cost function were $CF \approx 4.82 \times 2.20 \approx 10.60$ (in Figure 3), $CF \approx 4.23 \times 2.25 \approx 9.52$ (in Figure 4), and $CF \approx 4.43 \times 2.24 \approx 9.92$ (in Figure 5). On the other hand, if the optimization trials were perfectly converging to global solutions, all these results would have involved rotated versions of the same array configuration. This was not the case, since the optimization spaces were huge, and genetic algorithms cannot guarantee global convergence. However, the relatively similar levels of the cost-function values – i.e., 9.58, 10.60, 9.50, and 9.92 – demonstrated the success of the optimization trials, and indicated that a global convergence may not provide a significantly better result.

Similar to the results in Figure 2, alternative particles were tested in Figures 3-5, after optimal configurations were obtained with cubic particles. Comparing the results in Figures 2-5, one could observe that some array configurations were relatively more stable than others in terms of the particle geometry. As an example, for the results shown in Figure 3, replacing cubic particles with spherical particles led to $CF \approx 3.03 \times 1.63 \approx 4.94$, which was better than the performance (that is, 2.16) shown in Figure 2. It was remarkable that in all cases, octahedral particles significantly deteriorated the radiation characteristics, which may have been due to the smaller volume-filling ratio of those particles.

Finally, Figure 6 presents optimization results when the radiation at $\phi_0 = 45°$ was maximized, while different particles were used (the results for cubic particles were also presented in Figure 2). Optimal configurations obtained by using different types of particles seemed to be different from each other, while the results showed that quite successful radiation characteristics could be obtained with alternative particles. In fact, with these particles, the results were even better than those obtained when cubic particles were used. Specifically, the cost-function values were $CF \approx 4.86 \times 2.12 \approx 10.30$ with cylindrical particles, $CF \approx 4.86 \times 3.19 \approx 15.50$ with spherical particles, $CF \approx 3.51 \times 3.58 \approx 12.57$ with octahedral particles, and $CF \approx 4.45 \times 2.63 \approx 11.70$ with hexagonal particles, in comparison to 9.58 with cubic particles. We noted that side peaks occurred in the *x*-*y* plane, particularly when octahedral particles were used, while they could be suppressed by using alternative cost functions in genetic algorithms.

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Mobile-Phone RF/Microwave Exposure and Memory Performance Scores in Adolescents

The marketing of mobile phones to youngsters is no longer a forbidden subject, as it once was. Mobile phones – and especially smart phones – have become such a popular phenomenon that the marketing success to young people could perhaps be looked upon as by default or maybe by design, although it might be debatable either way. However, that's for another time. Nevertheless, France, among others, has banned the use of mobile phones in primary, junior, and middle schools, both inside the classroom and even outside, in the school playground [1, 2].

What is more, hundreds of millions of toddlers and teenagers now have their own handsets, or similar wireless devices or gadgets. Indeed, mobile phones may have replaced pacifiers for toddlers, or become high-tech babysitters for others. Mobile phones are turning up as common accessories for most teens. Reports suggest 95% of teens now have access to a smart phone [3]. Nevertheless, the potential impact of microwave and radio-frequency (RF) electromagnetic fields and radiation emitted by mobile phones and wireless devices on the cognitive functions of adolescents persists as a public-health worry [4, 5].

There are concerns because, for children who still have years of development ahead of them, any disturbance to brain function could lead to impaired learning ability. A remarkable cascade of neural activities is invoked during learning and memory, which include such functions as encoding, processing, and retrieval of information. Moreover, any lasting neurochemical effects could have important consequences in children's lives, including potential behavioral issues.

Some investigations have reported that exposure to mobile-phone RF/microwave radiation can affect such cognitive functions as attentional function, short-term memory tasks, information manipulation, or response reaction times in adults [6]. However, due in part to ethics issues regarding research studies involving children, very few studies have targeted adolescents and preteens.

A dozen years ago, two small-scale studies of young users were conducted using standard GSM 900 MHz mobile phones (a Nokia 3110 headset in normal-use position with a typical 0.25 W output power). One paper from the UK reported a slight trend toward speeding up of simple reaction time [7], whereas the other study from Finland did not detect any change in cognitive functions [8].

In the UK investigation, the effect on cognitive function was studied in 18 preteens who were 10 to 12 years of age [7]. The study involved a series of tests with three measures of cognitive performance: (a) reaction time (in ms), (b) accuracy for percent correct, and (c) a sensitivity index, which is a measure of the effect of distracting or novel information. The test sessions were conducted on sequential days. Each session took about 30 to 35 minutes to complete. This study found some trends toward faster reaction times, higher accuracy, and higher sensitivity in the presence of RF/microwave radiation from a GSM mobile phone than under sham exposure (power-off) conditions. However, none of these effects reached statistical significance.

The study in Finland recruited twice as many subjects, ranging from 10 to 14 years of age [8]. The subjects performed a battery of eight cognitive tests, twice in a counterbalance order, in separate sessions with the mobile phone on and with the mobile phone off, for sham exposure. The tests consisted of four reaction-time tasks and four short-term memory tests. The sessions were separated by 24 hours. The study did not show any significant differences between the mobile-phone power on-off conditions in reaction times or response accuracy over all tests or in any one of the tasks.

Combining the results of this study with those of the UK investigation, it may thus be concluded that RF/microwave radiation from GSM mobile phones has no acute effect on a 10-to-14-year-old's cognitive function, as measured by response time and accuracy. However, the numbers of subjects were small in both studies, which were acute and short-term in nature. The limitations make it difficult to draw any firm conclusions concerning the sensitivity of youngsters to RF/microwave radiation from mobile phones, even for acute exposures at low levels.

A couple of recent Swiss studies of adolescents have reported adverse effects on cognitive functions (specifically, memory-performance scores) that involve brain regions exposed to higher cumulative levels of RF/microwave radiation associated with GSM (900 MHz), GSM (1,800 MHz), and UMTS (2,000 MHz) mobile-phone use [9, 10]. The latest study was a continuation and expansion of a prior study. It employed a better estimation of absorbed RF/microwave radiation.

The aim of the first study was to investigate associations between memory performance and cumulative exposure to RF/microwave radiation from mobile phones [9]. It was a prospective cohort study, with 439 adolescents from 12 to 17 years of age as participants. At baseline or the beginning of the study, 412 (93.9%) of the participants owned a mobile phone; one year later, 425 study participants remained in the study. Of those, 416 (97.9%) owned a mobile phone. Mobile-phone-operator recorded data for 234 study participants were obtained between the beginning and end of the investigation; the average interval was 12.5 months.

Verbal and figural memory tasks at baseline and after one year were conducted using standardized, computerized cognitive tests. It is noted that different brain regions are known to be involved in verbal and figural memory tasks. In general, figural memory processes predominantly involve the right-brain hemisphere, whereas verbal memory tasks mostly involve the left hemisphere.

In the verbal memory task, word groups were memorized in 1 min. After 1 min, the subjects were asked to repeat the word groups. A score of 10 was recorded for remembering the correct word groups. In the figural memory task, pairwise symbols were memorized in 1 min. After 1 min, one part of the pairwise symbols was displayed and the matching part had to be found. A perfect score of 13 was recorded for correct responses. For both verbal and figural tests, a total of 2 min was allowed for test completion. Memory performance was assessed by the correct number of memorized word groups or symbols, respectively.

Exposure-assessment methods employed included questionnaires and mobile-phone-industry (operator) recorded user data for a subgroup of 234 adolescents. Exposure to various wireless devices in the immediate environment (access points, base stations, and RF broadcast transmitters) was enquired by questionnaire. It is noteworthy that self-reported call durations were seven times higher than what was recorded by their operators. RF/microwave exposure for the brain was analyzed using a longitudinal approach to investigate whether cumulative exposure over one year was related to changes in memory performance. All analyses were adjusted for relevant confounders, including media usage and motivation of the participants. It appeared that confounding did not have a substantial impact on the results.

As a special emphasis, absorption of RF/microwave energy in the brain was computed from propagation-scenario modeling and personal dosimeter measurements. The most relevant contributors for RF/microwave power deposition in the brain were calls on the GSM mobile phone networks (on average, 93.3% for the whole sample based on self-reported data, and 58.7% for the sample with operator data using operator-recorded information).

In this case, figural memory scores were found to be associated with cumulative RF/microwave brain exposure in adolescents. However, no association was observed for verbal memory performance. Higher cumulative RF/microwave exposure of the brain was associated with a correlated decrease in figural memory performance over a one-year period, and a stronger decrease was observed in right-sided mobile-phone users. In particular, results obtained in this study showed that compared to low-exposure groups (below 7.6 min/day, 710 mJ/kg per day for brain), significant decreases ($p < 0.05$) were observed in higher-exposure groups (18.6 min/day to 293.9 min/day, 1,854 mJ/kg to 16,233 mJ/kg per day for brain). Indeed, it was more so if adjusted for age, sex, school level, physical activity, education of parents, and time between baseline and end of investigation.

As mentioned, figural memory processes in humans are known to involve the right hemisphere of the brain. The observed effects on figural performance were thus consistent with the data that indicated 81.2% of the study participants reported mainly using mobile phones on the right side. However, the study authors advised that the observed associations should be interpreted with caution, because of the complexity and uncertainty of the correlations and exposure calculations.

The more-recent report was a follow-up study from the same research group. The analysis involved a larger population of adolescents (669 participants for figural memory and 676 participants for verbal memory). Some of the adolescents took part in the earlier study. It also used an updated individual RF/microwave exposure-estimation model [10].

The specific absorption rate (SAR) in the brain of each participant from exposure to mobile-phone emitted RF/microwave radiation was modeled. Namely, individual RF/microwave absorption in brain tissue for the population as a whole was estimated by using objectively recorded operator data from a subset of participants to calibrate self-reported call duration, to reduce misclassification.

Cognitive or memory performance was measured using a computerized testing system consisting of figural and verbal memory subtests, as in the case for the earlier study [10]. For the verbal memory task, participants were given 1 min to memorize five sets of two to five words grouped by their common higher-semantic category (for example, city: Amsterdam, Hamburg, Madrid, Rome, York). The target words were presented by starting with a different letter each time. Immediately after the presenting phase, participants were given a letter, and they had to recall the word starting with that letter and report the higher semantic category to which it belonged. This was repeated for 11 words, producing a maximum score of 11 points for the verbal memory task. For the figural memory task, participants were given 1 min to memorize 13 pairs of abstract figures. Immediately afterward, one item per pair was shown, and participants were asked to choose the correct counterpart out of five possible options. The matching task was repeated for 13 symbols, resulting in a maximum score of 13 points. For each of the two tests, 2 min were given to complete the matching task.

For each participant, the test started with the verbal-memory task. Linear-regression modeling was applied to verbal and figural memory-score changes over one year and to estimated cumulative brain exposure to RF/microwave radiation. Because of the hemispheric dependence of memory function, a laterality analysis was conducted for phone-call ear preference.

As in the earlier study, results of this one-year follow-up study did not suggest any association with verbal-memory performance. However, it found a potential adverse effect of brain exposure to RF/microwave radiation from mobile phones on figural cognitive functions that involve brain regions that were exposed during mobile-phone use. There was also a significant decrease in figural memory score with exposure of brain matter on the same hemisphere for right-side users.

The study showed decreased figural memory scores of -0.58 (95% CI: -1.17 to 0.01) per 953 mJ/kg per day increase in cumulative brain exposure of the whole sampled population ($n = 288$). The expected figural memory score could thus decrease by one unit within one year from a cumulative exposure of 1,643 mJ/kg per day (953/0.58) within that year. When only network-operator-recorded data were used for RF/microwave estimation ($n = 63$), the figural memory scores were -0.35 (-1.20, -0.50) and 341 mJ/kg per day. This would translate to a potential expected figural memory score decrease by one unit within one year from a cumulative exposure of 974 mJ/kg per day (341/0.35) within that year. Aside from differences in sample population size, the whole-sampled population included both sample populations with operator-recorded data and self-reported exposure, after calibration using operator data, which still may not have provided comparable representation of exposure.

This inverse association of cumulative RF/microwave brain exposure was also seen in the earlier paper [9]. Using the same procedure for estimating cumulative brain exposure to RF/microwave radiation, that paper found decreased figural memory scores in association with an increase in estimated cumulative RF/microwave brain exposure: -0.14 (95% CI: -0.40, 0.14) and 953 mJ/kg per day increase in cumulative brain exposure of the whole sampled population ($n = 381$). Accordingly, there would be an expected figural memory score decrease by one unit within one year from a cumulative exposure of 4,236 mJ/kg per day (593/0.14). When only operator-recorded data were used for RF/microwave estimation ($n = 211$), the figural memory scores were -0.25 (-0.41, -0.09) and 341 mJ/kg per day. This would give rise to a potential expected figural memory score decrease by one unit within one year from a cumulative exposure of 1,364 mJ/kg per day (341/0.25). (The numbers of participating adolescents quoted differed slightly from those reported in the earlier paper [9].)

Combining the two studies, as was done in the most recent paper, with a total of 669 adolescent participants, the analysis showed that an increase in cumulative RF/microwave exposure of the brain was associated with a significant decrease in figural memory score: -0.22 (-0.47 0.03) and 953 mJ/kg per day increase in cumulative brain exposure of the whole study population. The estimated figural memory scores would decrease by one unit within one year from a cumulative exposure of 2,695 mJ/kg per day (593/0.22). If only operator-recorded data were used for estimating RF/microwave exposure ($n = 274$), the figural memory scores were -0.26 (-0.42, -0.10) and 341 mJ/kg per day. This would suggest a potential expected figural memory score decrease by one unit within one year from a cumulative exposure of 1,312 mJ/kg per day (341/0.26).

A significant decrease in figural memory score with cumulative brain exposure was further seen in laterality analysis for right-side users of both the whole study population and those with only operator-recorded data. Analysis of participants with right-side preference (whole sample, $n = 532$ and operator data sample, $n = 217$) yielded figural memory scores of -0.38 $(-0.67, -0.09)$, for 953 mJ/kg per day and -0.29 $(-0.46, -0.11)$ for 341 mJ/kg per day increase in cumulative brain exposure, respectively. The estimated figural memory score would thus decrease by one unit within one year from a cumulative exposure of 2,508 mJ/kg per day (593/0.38) and 1,176 mJ/kg per day (341/0.29), accordingly.

The inverse association of cumulative RF/microwave brain exposure was thus consistently seen in the two linked studies and in the combined analysis of entire sample population who participated in the two linked studies, as well as in the adolescent population with operator-recorded exposure data. However, the strength of the association somewhat differed. The association was stronger in the second study than in the first study, although with a wider confidence interval. The association was statistically significant in the operator data, but not when combined with self-reported exposure estimates.

The question of whether RF/microwave radiation emitted by mobile phones during use could disturb brain activity in children and lead to impaired learning ability or behavioral problems has persisted for some time. To date, there remains a paucity of existing scientific data and relevant knowledge, including data on cognitive functions of adolescents. The question cannot thus be easily answered, based on existing scientific evidence. While reported results may lead to the conclusion that RF/microwave radiation emitted from GSM mobile phones does not produce acute effects on an adolescent's cognitive or memory function, available data suggest that significant decreases in figural memory were found to be consistently associated with cumulative exposure of the brain of adolescents to 1,000 mJ/kg to 4,000 mJ/kg per day over one year. Perhaps, a cautionary approach to risk management, especially in relation to children and adolescents, is warranted.

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Reflections After Three Years of This Column

Asta Pellinen-Wannberg

During the last three years, I have presented women working in radio science within this column. I took on this challenge since I saw that there is an overwhelming male dominance in the field. I have been wondering if this was a law of nature, or if there are some other reasons. I have learned a lot during these years from the women I have interviewed. Some scientists have been born in scientific dynasties: it has not been a big issue to continue on that path. This is valid for both genders. These people may have already learned the science jargon as kids, received support from home, and advice on how to avoid the pitfalls.

Today, many more people need to be trained to become researchers. We have talented young people from all over the world coming from homes without an academic tradition. It is thus important to offer these eager people equal opportunities, and to help them to find the right place that corresponds to their talents. Almost 30% of the Young Scientists at the second URSI Atlantic Radio Science Meeting 2018 (AT-RASC 2018) were female. I wonder how many of them will still be in the field 10 to 15 years from now, by which time they are supposed to have reached tenure within the education system, or permanent positions in industry or the business sector?

Today, we speak about a "leaky pipeline" concerning women leaving education or career paths in the fields of science, technology, engineering, and mathematics (STEM). It is still the case that if one has a talent for STEM, it is usually much easier to learn the tools required for the job than in many other fields, where you have to learn a lot of details by heart. From my own experience from quite many years ago, I got the impression that talented male students were considered to have a lot of potential, while the problem with successful female students was how to get them somewhere else. This might be one of the reasons why established female scientists often have concentrated on their own path.

Difficult issues for female scientists are a lack of support, supervision, and career prospects. This was well described in the 2012 Moss-Racusin et al. study [1] "Science Faculty's Subtle Gender Biases Favor Male Students." The postdoc phase often overlaps with the biological phase of reproduction. Family life can change one's possibilities to devote extensive periods to scientific work, even if there exists a good child-care system. The largest dropout of female researchers from academia in Sweden occurs at this phase when applying for tenure positions. I have an impression that it is not always your list of merits that helps you. Instead, you must try to minimize your number of "anti-merits," e.g., not having done things at the proper time or in the right order, because there is always a parameter on which to fail you.

Sexual advances can be another problem for young people. I have not seen very strong #metoo movements within science, but a month ago, at the Nordic Network for Diversity in Physics (https://norndip.com) conference in Stockholm, results from a questionnaire among graduate students were reported. As in the worlds of film, athletics, literature, arts, etc., there can bean uneven relations between young female candidates and established male professionals. In science, conferences are especially events where young ladies are wooed by gentlemen who could be their fathers. These can be from their own university, but also outside hunters. They can attract with promises of positions in their groups. It is very important that we make our young scientists aware that this can happen, and give them advice on how to deal with the situation if somebody seems to approach them with more than just a friendly agenda. I remember myself to have become very surprised and astonished a few times as a young student.

The Women in Radio Science column has had some effects. I was invited by the Research Organization of Information and Systems (ROIS) Female Research Development Office to Japan to speak about gender work in Sweden. There is an active effort initiated by the Japanese government to attract more women to science. During my visit, I was happy to interview a female Japanese scientist, Dr. Yuka Sato, who was at that time on her maternal leave, for the June, 2017, *Radio Science Bulletin*.

Last spring, I was asked to organize a Women in Radio Science (WiRS) event at the AT-RASC on Gran Canaria. As an attraction for the event, Dr. Anthea Coster, from MIT-Haystack, gave a highly appreciated talk about Dr. Lise Meitner. At this event, we also presented some gender statistics about the conference, as well as about URSI, in general. Among the 103 youngest participants who applied for the Young Scientist Awards, 30 were women, and of the 47 selected, 14 were female. This was almost 30%, and very positive. Twenty-three researchers of the 154 conveners were women: about 15%. The same relationship was valid among the Early Career Representatives: three females out of 20 scientists. As for the positions within URSI, the percentages of female officials are as follows: Scientific Commission Chairs, 10%; Vice Chairs, 20%; Member Committee Presidents, 9%; and the Board, 0% (no female representatives at all).

Examples are very important. From my childhood, I remember wondering why girls were not allowed to play soccer or ice hockey. There were no adult ladies doing such things at that time, or if they did, they were just strange. Fifty years later, we have world championships in both types of sports for women, with a large public interest. In athletics, there is a size difference between the players of the two genders, leading to separate leagues, but concerning talents in STEM there should not be a difference between women and men if they receive the same training. Marie Curie, Lise Meitner, and recently Donna Strickland confirm this. It is thus important that we have female scientists at all levels in different international organizations such as URSI: even in the Board. It is good for both genders of young researchers to see that this is normal.

In Sweden, the rule to have at least 40% of the underrepresented gender in various academic committees is a brilliant idea, otherwise one has to explain why not. It is usually easier to find and realize that there are proper female scientists than needing to write a strained explanation. Today, organizations and committees without female representation give an old-fashioned impression.

Reference

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INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC THEORY (EMTS 2019)

May 27-31, 2019, San Diego, CA, USA

First Call For Papers

The International Symposium on Electromagnetic Theory (EMTS 2019) will be held May 27-31, 2019, in San Diego, CA, USA. It is organized by Commission B (Fields and Waves) of the International Union of Radio Science (URSI), and is financially cosponsored by the United States National Committee for URSI (USNC-URSI) and the IEEE Antennas and Propagation Society (IEEE AP-S). EMTS 2019 is the 23rd event in the triennial series of international EMT symposia, which has a long history since 1953. Its scope covers all areas of electromagnetic theory and its applications. It is the major scientific event of Commission B, along with the URSI General Assembly and Scientific Symposium, Atlantic Radio Science Conference (AT-RASC), and Asia Pacific Radio Science Conference (AP-RASC). The venue is the hotel Westin San Diego, which is minutes from downtown activities including the San Diego Zoo, Balboa Park and its numerous museums, and the Gaslamp district for dining and nightlife. San Diego is the eighth largest city in USA, and is often referred to as "America's Finest City." Known for its great hotels, beautiful weather, pristine beaches, friendly people, and a plethora of entertainment, San Diego is a favorite destination for visitors across the globe. The San Diego airport is conveniently close to our symposium venue, so transportation to the conference will be quick and easy.

Welcome to San Diego in May 2019! The conference will offer plenary talks by distinguished speakers, regular oral and poster sessions, and a one-day school for young scientists (May 27), focusing on a topic in electromagnetics. A number of Young Scientist Awards will be offered, covering the registration fee and accommodation during the conference. In addition, business meetings, receptions, and a conference banquet will be organized. EMTS 2019 will focus on electromagnetic fields and their applications. Contributions on any aspect of the scope of Commission B are solicited. Some suggested topics are listed below. Special-session topics will be listed later on the Web site. All submissions (two to four pages in IEEE two-column format) will be reviewed by the Commission B Technical Advisory Board. Accepted and presented papers may be submitted to IEEE Xplore.

Important dates

- Paper submission site opens: July 15, 2018
- Deadline for paper submission: **October 22, 2018**
- Notification of acceptance: January 10, 2019
- Early-bird and author registration ends: March 30, 2019

Contact: Technical Program: Kazuya Kobayashi <kazuya@tamacc.chuo-u.ac.jp>
Local Organizing Committee: Sembiam Rengarajan <srengarajan@csun.edu>

Suggested Topics

1. Electromagnetic theory
- Analytical and semi-analytical methods
- Mathematical modeling
- Canonical problems
- Scattering and diffraction
- Inverse scattering and imaging

2. Computational methods
- Integral equation methods
- Partial differential equation methods
- High-frequency and hybrid methods
- Fast solvers and high-order methods
- Time-domain techniques
- Computational algorithms

3. Materials and wave-material interaction
- Metamaterials and metasurfaces
- Plasmonics and nanoelectromagnetics
- Electromagnetic bandgaps and other periodic structures
- Optical devices
- EMC and EMI
- Bioelectromagnetics

4. Antennas and propagation
- Antenna theory
- Antenna measurements
- Multi-band and wideband antennas
- Antenna arrays and MIMOs
- Wireless communication systems
- Guided waves and structures
- Random media and rough surfaces
- Millimeter wave/5G propagation
- Millimeter-wave antennas
- MIMO for 5G communication

5. Other topics
- History of electromagnetics
- Education in electromagnetics

www.emts2019.org

Report on 2018 IEEE Radio and Antenna Days of the Indian Ocean

The 2018 edition of the IEEE Radio and Antenna Days of the Indian Ocean (IEEE RADIO 2018) international conference was hosted once again in Mauritius, the country where the first three editions of the conference were organized in 2012, 2014, and 2015. Dr. Arjoon Suddhoo, Executive Director of the Mauritius Research Council (MRC), officially opened this sixth edition of the conference. It was held from October 15 to 18, 2018, at the Hilton Resort & Spa, Wolmar, Mauritius. The conference was managed by the Radio Society (Mauritius), and financially sponsored by the IEEE Antennas and Propagation Society (AP-S). IEEE RADIO 2018 was technically cosponsored by IEEE Region 8 and by the International Union of Radio Science (URSI). Researchers from Centrale Supélec, France; University of Mauritius; and Université de La Réunion formed the Local Organizing Committee.

Participants from over twenty different countries, spanning five continents, attended IEEE RADIO 2018. The conference featured fourteen regular sessions, covering diverse topics such as antenna design, devices and circuits, wave propagation and scattering, wireless communication systems, computational electromagnetics, and biological effects of electromagnetic fields. A tutorial on computational electromagnetics was presented on Monday morning. During the opening ceremony, the IEEE Ulrich L. Rohde Humanitarian Technical Field Project Award was presented to the IEEE Special Interest Group on Humanitarian Technology (SIGHT) Indian Ocean for the Agriculture, Climate and Technology in Indian Ocean Network (ACTION) project. Moreover, a SIGHT event was organized on Monday afternoon, during which representatives from different IEEE SIGHT groups presented their humanitarian activities and projects. Three internationally recognized scientists delivered invited talks during the conference.

A jury evaluated the oral presentations of students and young scientists. The best Young Scientist less than 36 years old received a shield and a cash prize of 300 Euros. The first, second, and third best student papers were awarded shields and cash prizes of 300 Euros, 200 Euros, and 100 Euros, respectively. The inaugural Industrial Engineering Paper Award, consisting of a shield and a cash prize of 300 Euros, was also presented.

Figure 1. The opening ceremony of RADIO 2018 on Monday, October 15, 2018.

Figure 2. The gala dinner with sega dance show, organized on the beach on Wednesday, October 17, 2018.

Figure 3. (l-r) The recipients of: the Young Scientist Award, Dr. Marc Dubois; the second best Student Paper, Mrs. Monique Gerber, represented by Dr. Tinus Stander; the first best Student Paper, Mrs. Marine Moussu; the third best Student Paper, Mrs. Siti Nailah Mastura Zainarry; the Industrial Engineering Paper Award, Dr. David Vizard; and the General Chair, Prof. Vikass Monebhurrun.

The 2019 edition of the IEEE RADIO international conference will be held from September 23 to 26, 2019, on Reunion Island.

Vikass Monebhurrun
General Chair, IEEE RADIO 2018
E-mail: vikass.monebhurrun@centralesupelec.fr

URSI Conference Calendar

September 2018

ICEAA 2018 - IEEE APWC 2018 - FEM 2018
Cartagena de Indias, Colombia
Contact: iceaa18@iceaa.polito.it, http://www.iceaa-offshore.org

October 2018

COMPENG
2018 IEEE Workshop on Complexity in Engineering
Florence, Italy, 10-12 October 2018
Contact: compeng2018@ino.cnr.it , http://compeng2018.ieeesezioneitalia.it/

RADIO 2018
IEEE Radio and Antenna Days of the Indian Ocean 2018
Mauritius,15-18 October 2018
Contact: http://www.radiosociety.org/radio2018/

ISAP 2018
2018 International Symposium on Antennas and Propagation
Busan, Korea, 23-26 October 2018
Contact: http://isap2018.org/

November 2018

APMC
Asia-Pacific Microwave Conference 2018
Kyoto, Japan, 6-9 November 2018
Contact: http://www.apmc2018.org/

LAPC 2018
Loughborough Antennas and Propagation Conference
Loughborough, United Kingdom, 12-13 November 2018
Contact: Poppy Seamarks, Tel: +44 (0)1438 767 304, Fax: +44 (0)1438 765 659, Email: lapc@theiet.org
https://events.theiet.org/lapc/

January 2019

USNC-URSI NRSM 2019
USNC-URSI National Radio Science Meeting
Boulder, CO, USA, 9-12 January 2019
Contact: Dr. Sembiam R. Rengarajan, Department of ECE, California State University, Northridge, CA 91330-8346, USA, Fax: 818-677-7062, E-mail: srengarajan@csun.edu; Logistics: Christina Patarino, E-mail: christina.patarino@colorado.edu, Fax: 303-492-5959, https://nrsmboulder.org/

March 2019

C&RS "Smarter World"
18th Research Colloquium on Radio Science and Communications for a Smarter World
Dublin, Ireland, 8-9 March 2019
Contact: Dr. C. Brennan (Organising Cttee Chair)
http://www.ursi2016.org/content/meetings/mc/Ireland-2017-CRS Smarter World CFP.pdf

AP-RASC 2019
2019 URSI Asia-Pacific Radio Science Conference
New Delhi, India, 9-15 March 2019
Contact: Prof. Amitava Sen Gupta, E-mail: sengupto53@yahoo.com, http://aprasc2019.com

May 2019

EMTS 2019
2019 URSI Commission B International Symposium on Electromagnetic Theory
San Diego, CA, USA, 27-31 May 2019
Contact: Prof. Sembiam R. Rengarajan, California State University, Northridge, CA, USA, Fax +1 818 677 7062, E-mail: srengarajan@csun.edu, http://www.emts2019.org

June 2019

EMC Sapporo & APEMC 2019
2019 Joint International Symposium on Electromagnetic Compatibility and Asia-Pacific International Symposium on Electromagnetic Compatibility, Sapporo
Sapporo, Japan, 3-7 June 2019
Contact: http://www.ieice.org/~emc2019/

September 2019

Metamaterials 2019
Rome, Italy, 16-19 September 2019
Contact: http://congress2019.metamorphose-vi.org/

RADIO 2019
IEEE Radio and Antenna Days of the Indian Ocean 2019
Reunion Island, 23-26 September 2019
Contact: http://www.radiosociety.org/radio2019/

November 2019

COSPAR 2019
4th Symposium of the Committee on Space Research (COSPAR): Small Satellites for Sustainable Science and Development
Herzliya, Israel, 4-8 November 2019
Contact : COSPAR Secretariat, 2 place Maurice Quentin, 75039 Paris Cedex 01, France, Tel: +33 1 44 76 75 10, Fax: +33 1 44 76 74 37, E-mail: cospar@cosparhq.cnes.fr http://www.cospar2019.org

August 2020

COSPAR 2020
43rd Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events
Sydney, Australia, 15-23 August 2020
Contact : COSPAR Secretariat, 2 place Maurice Quentin, 75039 Paris Cedex 01, France, Tel: +33 1 44 76 75 10, Fax: +33 1 44 76 74 37, E-mail: cospar@cosparhq.cnes.fr http://www.cospar2020.org

URSI GASS 2020
Rome, Italy, 29 August - 5 September 2020
Contact: URSI Secretariat, c/o INTEC, Tech Lane Ghent Science Park - Campus A, Technologiepark-Zwijnaarde 15, B-9052 Gent, Belgium, E-mail gass@ursi.org, http://www.ursi2020.org

May 2021

AT-RASC 2021
Third URSI Atlantic Radio Science Conference
Gran Canaria, Spain, 23-28 May 2021
Contact: Prof. Peter Van Daele, URSI Secretariat, Ghent University – INTEC, Technologiepark-Zwijnaarde 15, B-9052 Gent, Belgium, Fax: +32 9-264 4288, E-mail: peter.vandaele@ugent.be, http://www.at-rasc.com

A detailed list of meetings is available on the URSI website at http://www.ursi.org/events.php

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