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Implementation of e-CALLISTO Network for study of solar activities

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The Earth is influenced by the effects of the continuously varying solar wind, the flow of plasma and the embedded magnetic field from the Sun. Life on the earth is driven by the sunlight incident from the Sun. Therefore, the climate is critically sensitive to solar activities. The variation in the Sun's atmosphere has an important role in changing life on the earth and therefore it becomes necessary to monitor, observe and study solar activities. Many instruments and observatories have been keeping watch on Sun's activities. The Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) is one of them. It is popular, portable and low-cost instrument. All CALLISTO station spectrometers together form an e-CALLISTO network. The e-CALLISTO network is spread worldwide and has been providing observations from different countries. This paper reports the antenna and receiver of e-CALLISTO network. It represents the information about antenna especially Log-periodic Dipole Antenna (LPDA) which is low cost and easy to design which can help antenna designer to identify the benefits of LPDA. The e-CALLISTO network is still growing, therefore this may help the people who are going to work on solar activity or working on the e-CALLISTO network.

Keywords: Solar activities, CALLISTO, Log-periodic Dipole Antenna (LPDA), Low Noise Amplifier (LNA), Downconverter, Upconverter.

1 Introduction

Life on the earth is driven by the Sunlight incident from the Sun. The Earth is influenced by the effects of the continuously varying solar wind, the flow of plasma and the embedded magnetic field from the Sun. Therefore, the climate is critically sensitive to solar activities. The variation in the Sun's atmosphere has an important role in changing the life on the earth. It is necessary to study and understand solar activities[1].

In the 16th century, the first description of the Earth's magnetic field was given in De Magnete, by William Gilbert[2], revealing that the Earth itself is a great magnet. A study on earth's magnetic field carried out by Gauss and William Weber showed that systematic variations and random fluctuations, in the Earth's magnetic field concluded that the Earth is not an isolated body, but has been influenced by external forces, which we called as magnetic storms. Richard Carrington observed the first powerful geomagnetic solar storm on 1st September 1859. It was associated with a major Coronal Mass Ejection (CME) that travelled 150 million kilometres in 17.6 hours towards the Earth[3,4].

The impact of CME temporarily distorts the magnetic field of earth, changing the direction of compass needles and inducing large electrical currents in the Earth. This is called as geomagnetic storm[5].

Radio observation has been done since 1944 when J. S. Hey discovered that the Sun emits radio waves, in which more energy is released on a time-scale of a few minutes to tens of minutes[6]. The first Coronal Mass Ejection (CME) was discovered on December 14, 1971. The CMEs are large magnetically structured plasmas that are expelled from the Sun and propagate to large distances in the heliosphere[1].

The solar flares are the intense explosions on the Sun that expel a large amount of electromagnetic energy into space. The solar flares emission comes in many varieties, mostly due to a variety of different emission processes and material origins[7]. A sudden brightening in the solar atmosphere, dissipate energy across all the atmospheric layers. This energy is stored magnetically in the corona before the event which builds up gradually taking place as the result of deep-seated convective motions that deliver high magnetic stress in the form of non-potential magnetic fields. The solar flares produce radiation across the electromagnetic spectrum with different intensity[5].

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These can be observed by various method namely optical observations, radio observations, and space telescopes. These variations in solar irradiance have been studied from space for over two decades[8].

Nowadays ground-based spectral observations are being obtained in a wide frequency ranging from a few MHz to GHz with many spectrographs. The ground observatories are increasing rapidly. A few solar-dedicated imaging instruments are now available: the Gauribidanur Radio heliograph (40–150 MHz), the Owens Valley Radio Observatory (OVRO: 1–18 GHz), the Siberian Solar Radio Telescope (SSRT: 5.7 GHz), the Ratan-600 radio telescope (610 MHz – 30 GHz)[1]. In the microwave domain, the Nobeyama Radioheliograph (NoRH) was providing systematic images of the Sun at 17 GHz since 1992[9]. On March 31st, 2015 NoRH was shut down.

2 Materials and Methods

2.1 CALLISTO station

Compound Astronomical Low-Cost Low Frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) station can be formed using an antenna, an amplifier, a CALLISTO receiver (Heterodyne receiver) and a personal computer as shown in Fig. 1. CALLISTO is a programmable heterodyne receiver designed in 2006 in the framework of IHY2007 and ISWI by Christian Monstein as a member of the former Radio Astronomy Group (RAG) at ETH, Zurich, Switzerland. It uses a commercially available TV tuner (CD1316) to tune the frequency in the range of 45 MHz to 870 MHz with a resolution of 62.5 kHz. The obtained data is in Flexible and Interoperable Data Transfer (FIT) files with up to 400 frequencies per sweep. This data is transferred via RS-232 cable to a personal computer and is saved in it[10].

2.1.1 Antenna

The antenna was used to detect radio signals and fed them to the CALLISTO receiver. There are many different antennas that can be used to capture signals. Log Periodic Dipole Antenna (LPDA) is commonly used with the CALLISTO receiver. LPDA is attracted because of the broadband frequencies and more sensitivity to detect signal of the Sun, frequency independence and also, it is economical and practical to implement.

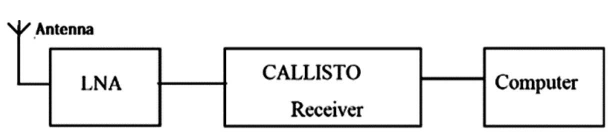

Fig. 1 — Block diagram of CALLISTO station.

In 1960, Isbell first introduced the broadband LPDA in free space[11]. It consists of an array of linear dipoles known as driven elements, each of different length and spacing between them. They have geometries that are specified by angles. The general configuration of a log-periodic array is described in terms of the design parameters; the geometric ratio τ, spacing factor σ, and half apex angle α are mentioned in following equations[12].

$$\tau = \frac{f2}{f1} \quad ...(1)$$

where, $f_2 > f_1$

$$\sigma = \frac{R_{n+1} - R_n}{2l_{n+1}} \quad ...(2)$$

$$\alpha = \tan^{-1}\left[\frac{1-\tau}{4\sigma}\right] \quad ...(3)$$

These antennas are primarily used in the 10 MHz to 10 GHz region in a variety of practical applications such as Television, point-to-point communication, feeds for reflectors and lenses etc.[13]. Due to the uniform spacing between the resonant frequencies of antennas in a log-periodic scale, log-periodic term is derived. The bandwidth of such antenna depends on the precision in manufacturing the smallest element in the array and the size of the largest element in the array.

The LPDA consists of a system of driven elements, but only a few elements in the system are active at driven frequency. Dipole elements of LPDA are of different lengths and different relative spacing. The lengths and relative spacing of elements continue to go on increasing smoothly in dimension, being greater for each element than for the previous element, it begins from the feed point of the array to its end point as shown in Fig. 2. This is an advantage upon which the design of the LPDA is based, and which permits changes in frequency to be made without greatly affecting the electrical operation. There is a smooth transition of frequencies along the array of the elements which forms the active region. This is high current region comprises 4 to 5 elements. The region changes as frequency changed but it stays near the elements whose length are nearly or slightly less than λ/2[14]. There are other antennas such as dish antenna, bi-conical antenna and Long Wavelength Antenna (LWA) which are useful to observe the radiation in VLF and VHF/UHF band[15].

2.1.2 CALLISTO receiver

CALLISTO receiver uses a commercial TV tuner to tune at a desired frequency. ATmega16 microcontroller is used to control and manipulate data coming from LPDA is shown in Fig. 3.

The electronic circuits like IF amplifier and filters (High Pass, Low Pass, and Band Pass etc.) are used along with microcontroller to produce final data. The microcontroller is also used to communicate with PC using RS-232 protocol via standard com port of PC. There are many versions of the CALLISTO receivers available out of which some have the latest firmware and support windows 7, 8, 8.1 and 10[15].

2.1.3 Low Noise Amplifier (LNA)

Radio Frequency (RF) devices receive and transmit signals from 3 kHz to 300 GHz, so LNA is essential to amplify the desired signal[16]. LNA is a device that amplifies the very weak signal. Such a signal is captured by an antenna. Usually, LNA is mounted near the antenna. A low noise amplifier is a very important component in receiver applications especially when it is required to have a pre-amplifier[17]. With modem solid-state devices and integrated circuits, it is possible to realize amplifiers that exhibit an extremely high voltage gain, low noise figure with reasonable power[18]. Many LNAs are available in market that are suitable for e-CALLISTO with different types of matching circuits at both input and output side. The most important factors in LNA design are low noise figure, moderate gain, matching and stability[19]. Some time for weaker signal Tower Mounted Amplifier (TMA) along with LNA is used.

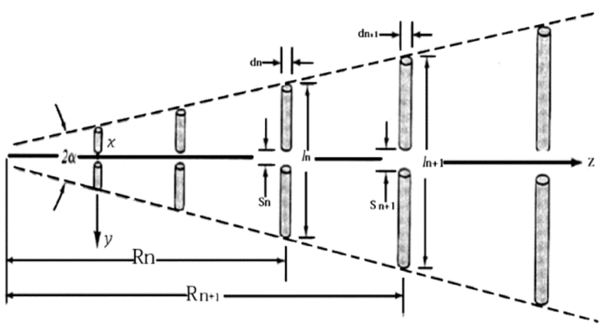

Fig. 2 — Structure of LPDA[14].

2.1.4 Cables and Connectors

Many types of coaxial connector are available in RF and microwave applications for a specific purpose. The performance of connector is affected by the quality of the interface. If the diameters of the inner and outer conductors vary from the nominal design or poor plating, the quality will degrade the reflection coefficient and resistive loss will take place at the interface[20]. Not all cables are suitable for the CALLISTO receiver because of weak signals. The interference of noise may highly introduce because of various frequency signals in surrounding[21].

The coaxial cable may have better noise immunity if shield is of good quality. The coaxial cables are available in various types such as RG58-f, RG58-U, RG6-f, RG6-U RG8-U, LMR300, LMR400, and RG214 and so on and so forth. These types describe the quality of cable as well as shielding types[22].

2.1.5 Up and Down Converter

RF up-converters and RF down-converters are the electronic assembly blocks that converts microwave signals to different range of frequencies for further processing. They are designed to produce an output signal frequency for a particular input frequency band. The frequency range of CALLISTO can be

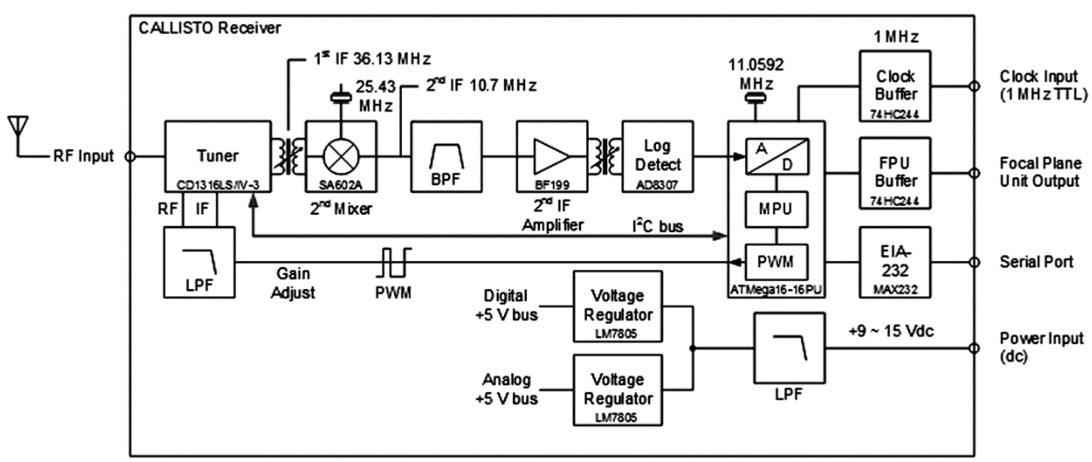

Fig. 3 — Block diagram of CALLISTO Receiver[15].

expanded to the desired range by switching a heterodyne using an up-converter or a down-converter. RF up-converters are designed to convert RF signals to a higher frequency signal. Whereas RF down-converters are designed to convert microwave signals to lower frequency range [23, 24].

Up-converter is used to convert frequency band below to 45 MHz to acceptable frequency band (45 MHz to 870 MHz). On the other hand, the down-converter is used to convert frequency band above 870 MHz to acceptable frequency band (870 MHz to 45 MHz). This frequency conversion is called heterodyning[24].

2.1.6 Personal computer

The personal computer is used to control, monitor of CALLISTO receiver. FIT Files are stored locally andare sent to the central hub located near Zurich, Switzerland. Any standard Windows 7 or Windows 10 PRO compatible PC can be used to operate CALLISTO instrument. Essential specifications for PC are as follows:

- Windows 7 or Windows 10 PRO operating system.
- 64-bit processer of any type.
- RAM ≥ 2 GByte
- HD or SD ≥ 500 GByte
- Keyboard, mouse and monitor.
- A UPS to cope with power
- Internet access for FTP-upload ≥ 1KByte/sec
- Hunt, shed or observatory to host the instruments.
- 1% Full-time equivalent (FTE) to operate and maintain the system, for e.g. installation of Windows updates.

2.2 e-CALLISTO Network

A worldwide network called Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (e-CALLISTO) is observing the solar activity. The CALLISTO spectrometer is a heterodyne receiver, a program under a framework of the International Heliophysical Year (IHY) 2007 and the International Space Weather Initiative (ISWI) lead by Christian Monstein at ETH Zurich, Switzerland is used for observation of solar radio bursts, Coronal Mass Ejection (CME) and RFI-monitoring for astronomical science, education and outreach[10]. Its' website is www.e-callisto.org. The e-CALLISTO network system observes the Sun for 24 hours every day. Many countries are making efforts to join e-CALLISTO network to detect solar flares and CMEs forthe past several years. This leads to detection of many solar flares and CMEs in many countries. In the past few years, many instruments have been deployed; eight spectrometers in India: Ootytwo, Gauribidanur, Gandhinagar, Ahmedabad, Sangli, Nashik, Pune, and Udaipur out of which five (Pune, Udaipur, Gauribidanur, Nashik & Ooty) are active and have been sending the data continuously (Fig. 4) shows the type-II Solar radio burst observed by Ooty.

One CALLISTO is in Badary, Russian Federation, two instruments in Daejeon, South Korea, two are in Hawaii, three instruments deployed in Australia, one in Costa Rica, two in Mexico, two in Brazil, three in Mauritius, five in Ireland, one in Ondrejov, Czech Republic, two instruments are in Mongolia, one in Germany (Essen), three in Cohoe and Anchorage/Alaska, two in Kazakhstan, one in Egypt, one in Kenya, one in Sri Lanka, four in Italy, two in Slovakia, two in Belgium, four in Finland, eight in Switzerland, four in Spain, five in Malaysia, three in Indonesia, one in Scotland/UK, one in Peru, one in Kigali, Rwanda, six in Austria, one in Pakistan, two in Denmark, one in South Africa, two in Kangerlussuaq, Greenland, one in Japan, one in Montevideo, two in Norway, one in Nepal, two in Thailand and two in Ethiopia[15]. Hence, their network is still growing up.

3 Results and Discussion

Coverage from different instruments located worldwide are discussed here. Figure 5 show that there are66 CALLISTO solar radio spectrometer which are operating across the world. Blue dot shows no data from instrument, green dot shows data two days ago and red dot shows currently working and sending data[15].

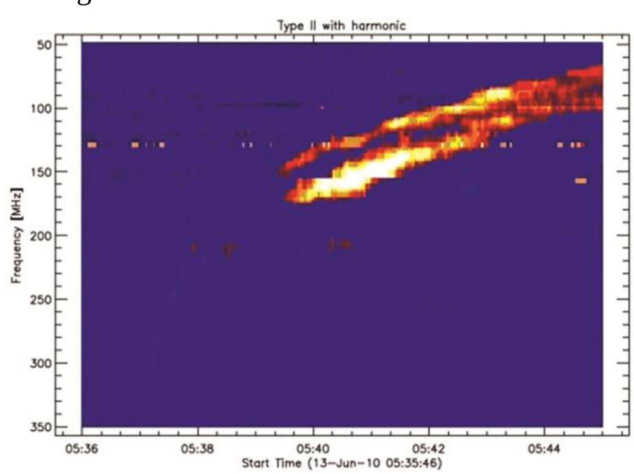

Fig. 4 — Type II Solar radio burst observed by Ooticallisto observatory, on June 13th 2010[15].

Table 1 — Spectrometers operating in India.

Name / Location of the station	File ID	Observing Frequency	Antenna type
TIFR, Ooty Tamil Nadu, India	OOTY	45 MHz - 450 MHz.	Linear polarized LPDA
IIA in Gauribidanur Bangalore, India.	GAURI	45 MHz - 410 MHz.	Linear polarized LPDA
University of Pune, Institute for electronic science.	INDIA-IISERP	45 MHz - 870MHz.	LPDA
Udaipur Solar Observatory, Rajasthan,	INDIA-UDAIPUR	45 MHz - 220MHz.	LPDA
NASHIK observatory Nashik, India	INDIA-Nashik	45 MHz - 870MHz.	LPDA, Horizontal polarized

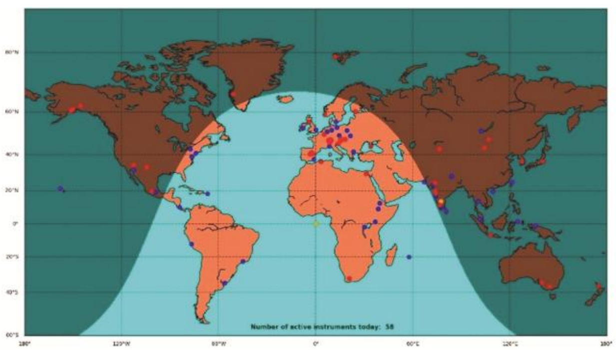

Fig.5 — Active instruments as on 06/01/2021 worldwide[15].

Worldwide, 66 CALLISTO stations out of 178 CALLISTO stations are sending data to the server. The instrument at Metsähovi observatory, Finland has small LPDA attached to the 37 GHz parabolic dish, tracking the Sun which observes from 170 MHz to 870 MHz in linear, horizontal polarization. Ondrejov and Czech Republic observatory observe using German Radar dish 7m diameter with linear polarized feed that cover 150 MHz to 870 MHz frequency. Bleien observatory, Switzerland observes using a parabolic dish with 7m diameter, tracking the Sun with LPDA as feed observing 170 MHz to 870 MHz in two polarizations: LHCP and RHCP. Royal observatory, Belgium with Log-per feed is attached to an old parabolic dish that tracks the Sun with linear polarization at 45 MHz - 870 MHz. Birr Castle, Ireland observing in linear horizontal polarization by using two bands, 45 MHz to 870 MHz and 20 MHz to 90 MHz by tracking the Sun. The instrument at Anchorage, Alaska has log-periodic dipole antenna horizontally polarized, tracking the Sun only in azimuth and observees in the range 45 MHz to 870 MHz. KASI Daejeon, South Korea has Large LPDA with horizontal polarization tracking the Sun and observes at 45 MHz to 870 MHz. RCAG, KhurelTogoot near Ulaan Baatar, Mongolia is observing at 175 MHz to 450 MHz with horizontally polarized LPDA in fixed sky position at the Sun-rise. ISTP Badary, Russian Federation has a log-periodic dipole antenna mounted on the upper rim of a dish with polarization rotating while the Sun is tracked during the day. It observes from 45 MHz to 450 MHz. The Station 'Orbita' near Almaty, Kazakhstan and having LPDA mounted at the lower rim of the 12m dish that observes 45 MHz to 870 MHz in linear horizontal polarization. IIA Gauribidanur, Bangalore, India is observing at 45 MHz to 410 MHz with linear polarized log-periodic dipole antenna (LPDA) pointing to zenith. The TIFR, Ooty, India has linear polarized LPDA pointing to zenith and observing at 45 MHz to 450 MHz. UoM, Poste de Flacq Mauritius is observing at 45 MHz to 870 MHz with the linear polarized LPDA. UNAM, Mexico has linear horizontally polarized LPDA that observes 170 MHz - 450 MHz frequency. Hans Michlmayr Perth, Australia observations are at 45 MHz to 870 MHz with linear horizontally polarized LPDA tracking the Sun15.Hence, all CALLISTO instruments together form the e-CALLISTO network. Whereas, for data handling several IDL, PERL and Python routines are used. The details of instruments providing coverage in India are shown in Table 1.

4 Conclusion

Life on the earth is driven by the Sun radiations incident from the Sun. The climate on the earth is critically sensitive to the solar activities. Radio bursts from the solar corona can provide clues to forecast space-weather hazards. The solar events happen to occur continuously. This leads to the study of the solar activities in the MHz to GHz frequency range of spectrum. Observations from satellites have made exceptional progress in the investigation of the Sun in the past decade. The CALLISTO solar radio spectrometer is a low-cost instrument that is very useful to observe dynamic solar activities. CALLISTO station is formed using an antenna mostly LPDA, an amplifier, a CALLISTO receiver (heterodyne receiver) and a personal computer. It is theprogrammable heterodyne receiver designed 2006 in the framework of IHY2007 and ISWI Christian Monstein, a member of former Radio Astronomy Group (RAG) at ETH, Zurich, Switzerland. The data obtained from CALLISTO are

FIT files with up to 400 frequencies per sweep. All CALLISTO station spectrometers together form an e-CALLISTO network. e-CALLISTO has been proven to offer great advantages for observing solar radiations for several years. Presently, there are 66 active CALLISTO stations out of 178 CALLISTO station installed are sending data regularly to the server formed worldwide. CALLISTO can be extended to measure a frequency range above 870 MHz and below 45 MHz using down-converter and up-converter respectively.

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References

1 Pick Monique, & Vilmer Nicole, *Astron Astrophys*, 16 (2008) 1.
2 Freudenthal Gad, *The University of Chicago Press*, 74 (1983) 22
3 Goldreich P, Murray N, Willette G, & Kumar P, *Astrophys J*, 370 (1991) 752.
4 Soojung-Kim Pang Alex, *Am Sci*, 95 (2007) 538.
5 Orchiston Wayne, *The New Astronomy: Opening the Electromagnetic Window and Expanding Our View of Planet Earth* (Springer), 2005, 191.
6 Hev J S. Parsons S J & Phillips J W, *Mon Notices Royal Astron Soc*, 108 (1948) 354.
7 Asai A, Ishii T T, Kurokawa H, Yokoyama T & Shimojo M, *Astrophys J*, 586 (2003) 624.
8 Benz A O, Monstein C, Meyer H, Manoharan P K, Ramesh R, Altyntsev A, Lara A, Paez J & Cho K S, *Earth Moon Planets*, 104 (2009) 277.
9 Scafetta N & Mörner N A, *Pattern Recognit Phys*, 2 (2014) 31.
10 Benz Arnold O, Monstein Christian, & Meyer Hansueli, *Sol Phys*, 226 (2005) 143.
11 Isbell D E, *IEEE Trans Antennas Propag*, 8 (1960) 260.
12 Kale Vijay S, & Patil Dnyandev B, *Instrumentation and Control Engineering*,3 (2015) 83
13 Carrel R L, *IRE International Conversion Rec*, 1 (1961) 61.
14 Balanis Constantine A, *Antenna Theory - Analysis and Design* (a John Wiley & Sons, Inc. Publication), 2005, 619
15 Ali M. O., Hamidi Z. S., Shariff N. N. M., Faid M. S., Sabri SNU, Nurulhazwani Husien, Zainol N H & Monstein C, *J Ind Eng Manag*, 1 (2017) 1.
16 Gotmare Gunjan S, Yadav Arpit & Badjate Sanjay, *Int Res J Eng Technol*, 02 (2015) 1892.
17 Sadik Ulker, *Int J Artif Intell*,3 (2012) 99.
18 W Marshall Leach, *IEEE*, 82 (1994) 1515.
19 Senthil kumar D, khot Uday Pandit, & Jagtap Santosh, *Int J Eng Res Appl*, 3 (2013) 403.
20 Robert John, *White Paper*, (2014) 1.
21 Mario A Maury, *Microw J (Int Ed)*, (1990) 1
22 Luyan Qian & Zhengyu Shan, *Coaxial Cable Modeling and Verification*, Bachelor of Science thesis, Blekinge Institute of Technology, Sweden, 2012.
23 Zhao Z., Magierowski S, & Belostotski L, *Int J Circuit Theory Appl*, 42 (2013) 1211.
24 Wan Qiuzhen, Wang Chunhua, & YU Fei, *Radio engineering*, 21 (2012) 752.