Project: IEEE P802.15 Working Group for Wireless Speciality Networks (WSNs)

Submission Title: Two-Step Angle-of-Arrival Estimation for Terahertz Communications

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Re: 15-17-0588-00-thz-multifreqeuncy-measurements

Abstract: This contribution presents an AoA estimation algorithm in two steps based on the correlation of power angular spectra (PAS) in different frequencies. A low frequency radio frequency (RF) frontend is applied for a rough and fast AoA estimation in the first step and the THz RF frontend estimates the precise AoA within the angular range confined in the first step to reduce the time consumption of AoA estimation. The correlation of PAS in different frequencies is the premise of the algorithm and is validated with a broadband channel sounder in a typical application scenario of indoor THz communication. Finally, the algorithm efficiency is analyzed with two exemplar scanning resolutions.

Purpose: Information of the IG THz

Two-Step Angle-of-Arrival Estimation for Terahertz Communications

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The contribution is an extension to [1] and based on [2].

Outline

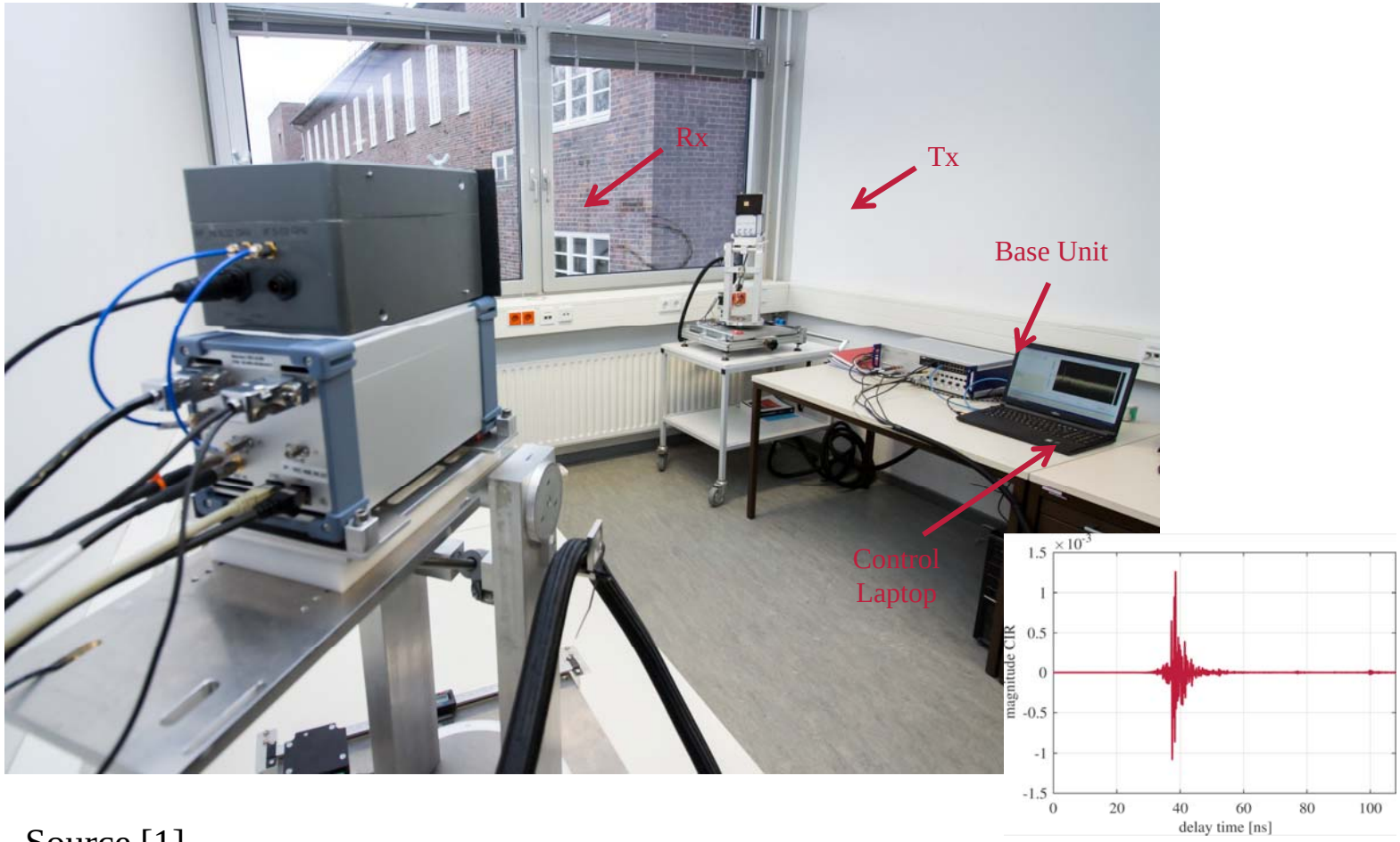
- Motivation
- Measurement Campaign
- Two-Step Angle-of-Arrival Estimation
- Demonstration
- Conclusions

Motivation

- The alignment of high gain antennas used for 300 GHz links is challenging especially in the device discovery phase during the set-up of the connection.
- Brute-force scanning of the angle-of-arrival at the receiver and of the angle-of-departure at the transmitter is too time-consuming.
- Therefore, a two-step process can be applied, where rough estimations of the angles are derived at lower frequencies with antennas having lower gains in the first step [3].
- A pre-requisite to apply such a method are similarities of the channel at the higher and lower frequencies.
- In [1,2] a comparison of measured spatial channel characteristics at carrier frequencies of 9 GHz, 64 GHz and 304 GHz using an ultra-wideband channel sounder [4] has been provided already. A short summary of these reuslts will be given also in this presentation.

Summary of Results from 15-17-0588-00-thz-multifreqeuncy-measurements [1]

TUBS‘ Time-Domain Channel Sounder



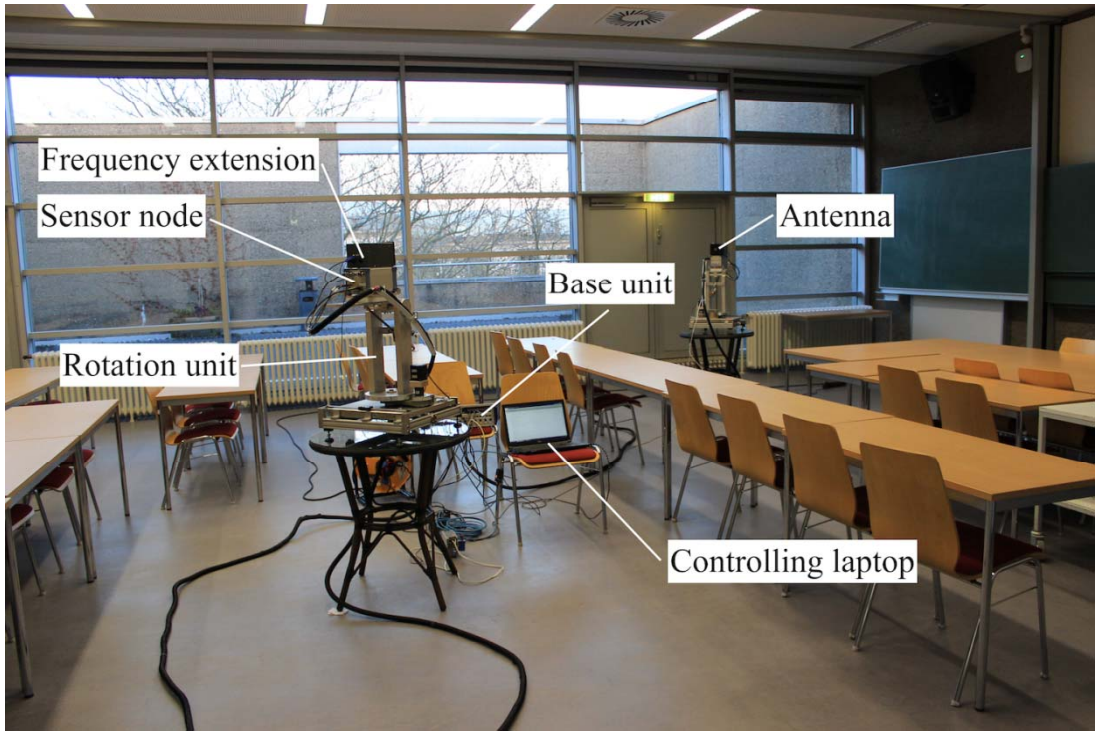
Source [1]

Technical Parameters of the Channel Sounder

Parameter	Value
Clock Frequency	9.22 GHz
Bandwidth	~ 8 GHz
Chip duration	108.5 ps
M-sequence order	12
Sequence length	4095
Sequence duration	444.14 ns
Subsampling factor	128
Acquisition time for one CIR	56.9 µs
Measurement Rate	17,590 CIR/s
Center Frequencies	9.2 / 64.3 / 304.2 GHz
SISO/MIMO	up to 4x4

Source [1]

Measurement Scenario (Lecture Room)

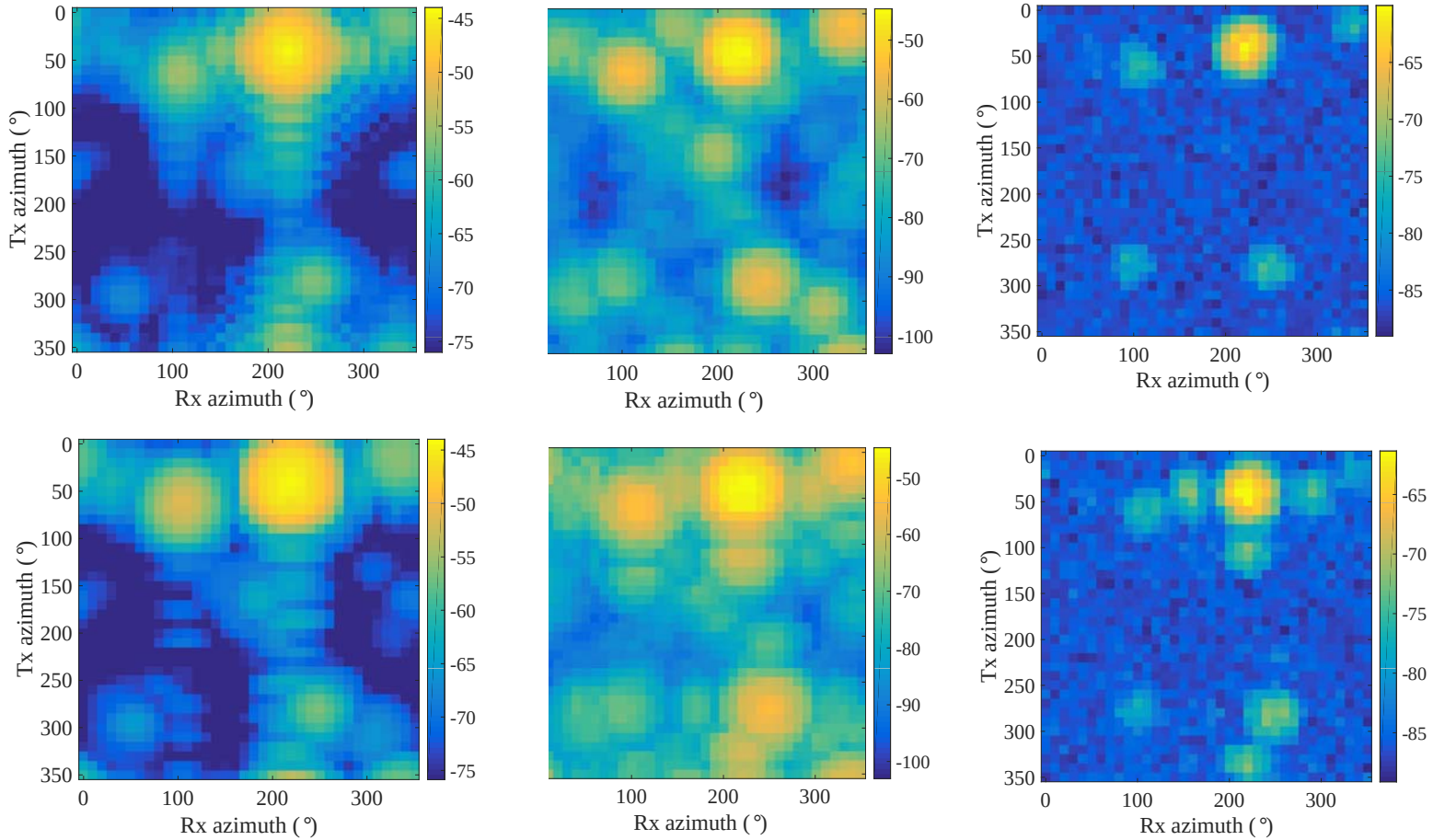


Source [1]

Measured Power Angular Spectra

Horizonatl polarization

vertical polarization



9 GHz

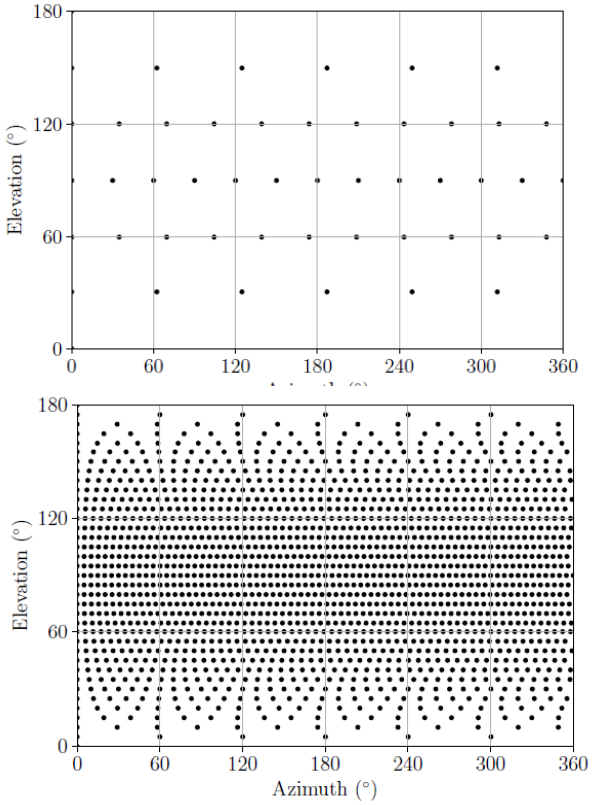
60 GHz

300 GHz

Source [1]

Two-Step Angle-of-Arrival Estimation

Pre-defined searching directions (different resolutions)



98 scans

1296 scans per AoA/AoD pair found in step 1

Algorithm 1 Two-step AoA estimation

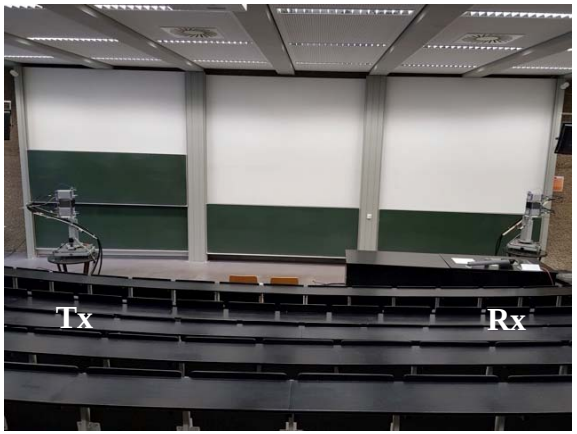
#1 transmits with an omni-directional antenna at low frequency
for every section main lobe direction of #2 **do**
  if #2 detects a signal higher than the noise level **then**
#2 transmits in the current main lobe direction at low frequency
    for every section main lobe direction of #1 **do**
      if #1 detects a signal higher than the noise level **then**
a pair of AoD and AoA is found
      end if
    end for
  end if
end for
for every pair of AoD and AoA **do**
  for every beam main lobe direction of #1 within range of the section **do** #1 transmit in the selected direction
    for every beam main lobe direction of #2 within range of the section **do**
      if #2 detects signal in the selected direction **then**
a pair of AoD and AoA is found
      end if
    end for
  end for
end for

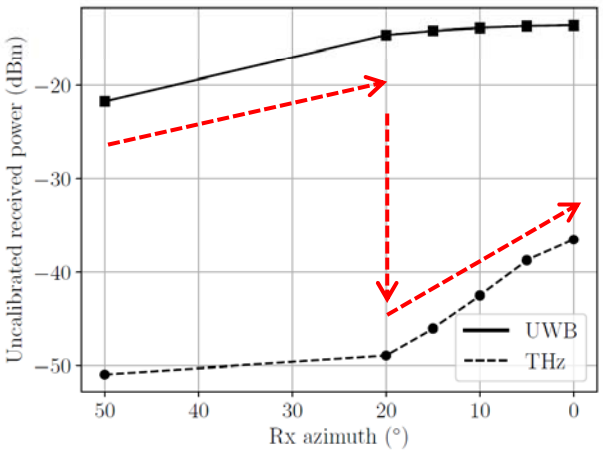
Full scan with 5° resolution would require **3515625** scans => **Speed up** by a factor of up to **2521**

Demonstration

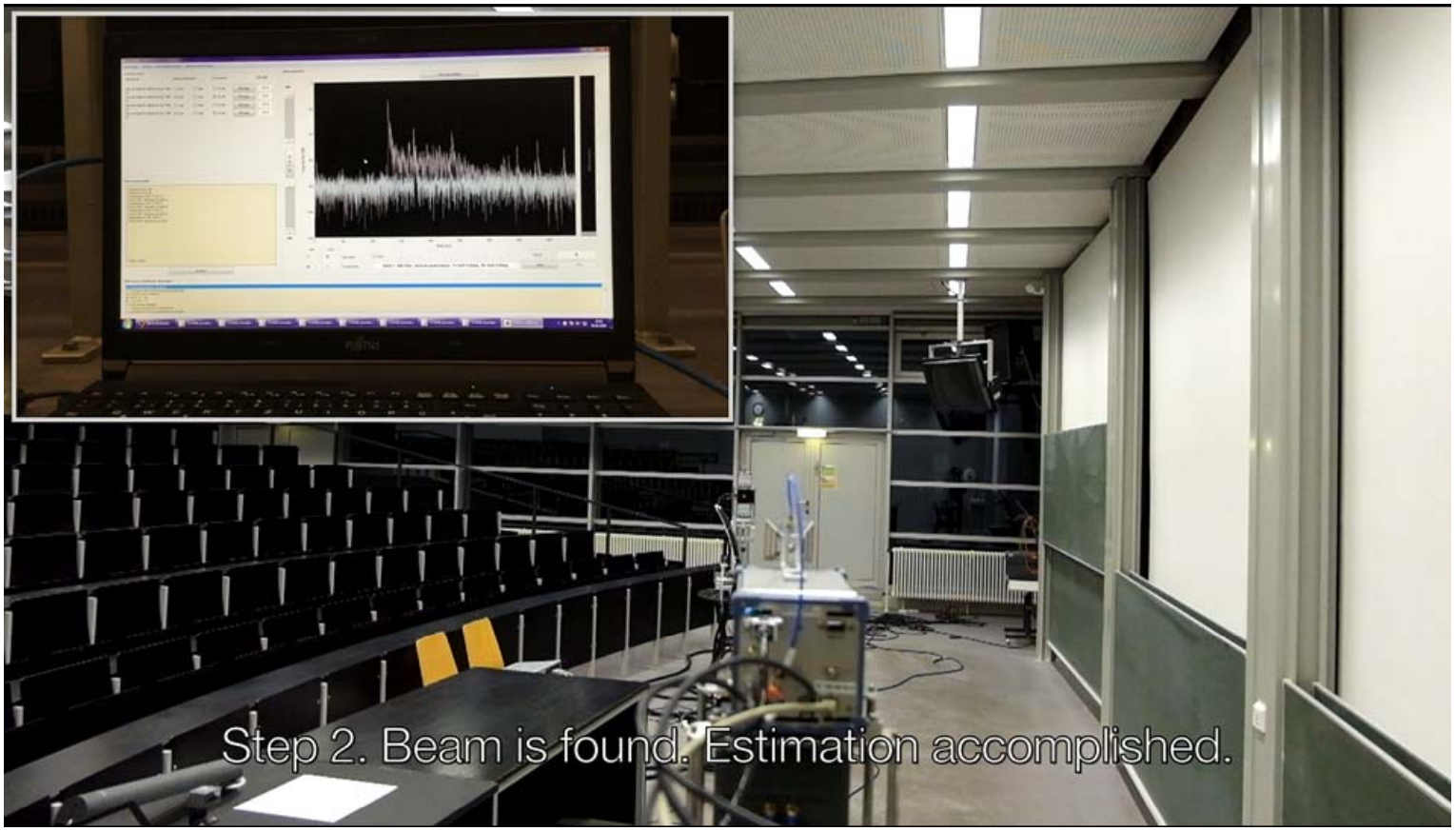
Using the Channel Sounder for a Demonstration of the two-step Beam Searching Concept

- Demonstration in a large lecture hall
- Mechanical steerable Rx
- Rx is following received power
  - Step 1: 30° increment at lower frequency
  - Step 2: 5° increment at 300 GHz





Beam Searching „in Action“



Conclusion

- A two-step AoA estimation algorithm, which aims to achieve a balance between precision and estimation time for device discovery at THz communication systems
- In the first step of the algorithm, rough estimates of AoD and AoA are searched individually at a low frequency band.
- Based on the results, the optimal AoD and AoA combination is estimated with high precision and within the rough region that is found in the first step
- The algorithm has been demonstrated in a larger lecture room scenario.

References

[1] T. Kürner, B. Peng, K. Guan, S. Rey, Multi-Frequency Measurements at 9, 64 and 304 GHz using an Ultra-Wideband Channel Sounder, IEEE doc. 15-17-0588-00, IEEE 802 Plenary, November 2018, Orlando

[2] T. Kürner, B. Peng, K. Guan, S. Rey, Two-Step Angle-of-Arrival Estimation for Terahertz Communications Based on Correlation of Power-Angular Spectra in Frequency, Proc. European Conference on Antennas and Propagation EuCAP 2018, London, March 2018, electronic publication, 5 pages

[3] B. Peng, S. Priebe, and T. Kürner, “Fast Beam Searching Concept for Indoor Terahertz Communications,” in Proc. 8th European Conference on Antennas and Propagation (EUCAP), pp. 483–487, IEEE, 2014.

[4] S. Rey, J. Eckhardt,. Peng, K. Guan, T. Kürner, Channel Sounding Techniques for Applications in THz Communications, 2nd Workshop on THz Communications (THZCOM) at the 9th International Congress on Ultra Modern Telecommunications and Control Systems, 8 November 17, 5 pages.