# DRSS-based Factor Graph Geolocation Technique for Position Detection of Unknown Radio Emitter

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***Abstract*—This paper proposes a new factor graph (FG) geolocation technique utilizing differential received signal strength (DRSS) for location detection of a single static unknown (anonymous) radio wave emitter. The use of DRSS-based FG (DRFG) technique is to solve the problem of conventional received signal strength (RSS)-based FG (RFG) technique which is unable to estimate the position of a single static unknown radio wave emitter without the knowledge of its transmit power knowledge. However, in practice, the transmit power information from the signal transmitted by the unknown target emitter is unavailable. It should be noticed that the knowledge of the transmit power of the target is necessary for calibration/reference of the RSS values of training signal sent from the monitoring spots. In this paper, we propose a new DRFG technique to eliminate the necessity of transmit power information, and hence this technique successfully estimates the position of an unknown radio emitter. The performance of the proposed technique is evaluated in the terms of root-mean-square error (RMSE). The results confirm that the proposed technique accurately estimate the location of unknown target, while the conventional RFG fails when the transmit power of monitoring spots are unequal to the transmit power of the unknown target.**

## I. INTRODUCTION

Wireless geolocation has been of significant importance to enable the location based services and applications. Hence, this research field has attracted considerable attention in the past two decades. The location based services and applications have become a necessity for human life, e.g., Emergency-911 (E-911), vehicle navigation, health care, and location-sensitive billing [1]–[3]. One of challenging problem in wireless geolocation is to estimate the position of a single static unknown (anonymous) radio wave emitter. This problem is also known as passive radio positioning system [4], [5]. The location detection of unknown radio emitter is very important for helping people in disastrous situations, e.g., finding missing people after disaster, the victims who are buried due to landslide, tsunami, and/or earthquake. It is also important for monitoring of illegal radio emitter to prevent public broadcasting from being jammed.

In this paper we consider the use of factor graph (FG) for detection of the position of the unknown radio target. The FG techniques improves the accuracy of the estimate because the probability marginalization is performed by message passing using sum-product algorithm. The FG also reduces the computational complexity of geolocation algorithm due to the fact that the the complex global function is decomposed into several local functions. Furthermore, the messages are in the form of the mean and variance only, if the measurement error follows Gaussian distribution [6], [7].

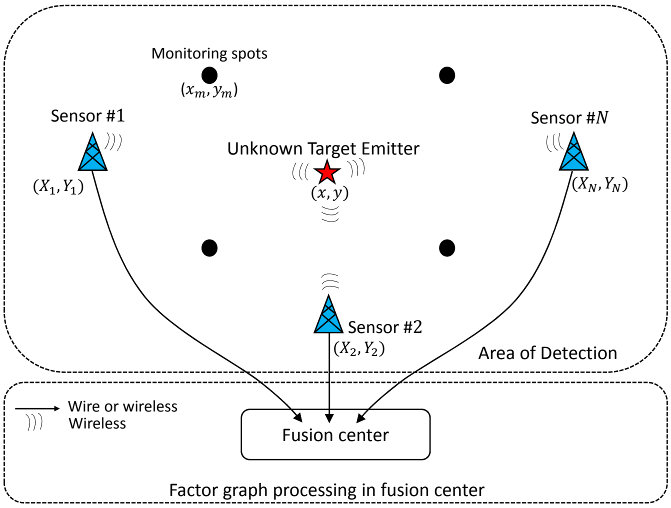



Fig. 1. Basic structure of FG-based geolocation techniques with $N = 3$ sensors consisting of a single static unknown radio wave emitter, 4 monitoring spots (monitoring spots are only required for the conventional RFG and the proposed DRFG technique).

Since the FG was introduced into geolocation technique for the first time by [8], there are many FG-based techniques[1] developed according to the measurement categories, e.g., received signal strength (RSS) [9], [10], direction of arrival (DOA)[2] [11], time difference of arrival (TDOA) [12], and TOA [7]. The basic structure of the FG-based technique is shown in Fig. 1. It should be noticed that the RSS measurement has several advantages compared to the TOA, TDOA, and DOA measurements; which are: (i) The RSS parameter can be measured without requiring an array or direction antenna, while the DOA measurement requires array antenna. (ii) The presence of perfect synchronization between target and sensors, and among the sensors is not required in the RSS measurement,

[1]The term "techniques" in this paper refer to "geolocation technique" except specified.

[2]We use DOA acronym instead of angle of arrival (AOA) for better expression.

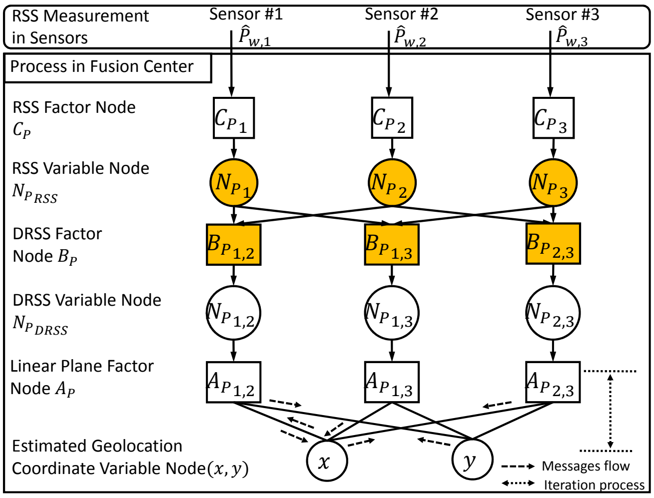



Fig. 2. The proposed DRFG for geolocation technique with $N = 3$ sensors and $\hat{P}_{w,t}$ being the input in units of watt. The new proposed nodes are marked by yellow. The message flow arrows are shown in part to avoid over crowded of the figure.

while the perfect synchronization is required for both the TOA and TDOA measurements. (iii) In the RSS measurement, all multipath can be captured by available fingerprints,[3] while the TOA, TDOA, and DOA measurements suffer from severe multipath effects. Furthermore, In fact, the RSS measurement has been already specified in IEEE 802.11 standard [9].

The RSS-based FG technique (RFG) in [9] uses the pattern recognition (fingerprinting) technique. The sensors measure the patterns or fingerprints of the RSS of training signal sent from the monitoring spots. The position of the target is estimated based on the resemblance between the RSS of the signals sent from target and the training signal sent from monitoring spots, where the position of monitoring spots are known [9]. It is shown in Fig. 1 that the conventional RFG technique utilizes monitoring spots.

However, the conventional RFG technique in [9] can not estimate the position of an unknown radio emitter because the technique requires the knowledge of the absolute value of the transmit power. Nevertheless, in practice, the transmit power information from the signal transmitted by the unknown target emitter is unavailable. It should be noticed that the knowledge of the transmit power is necessary for calibration/reference of linear approximation process using training signal sent from the monitoring spots.

Thus, the DRSS-based FG (DRFG) technique is proposed in this paper to solve the problem, where the necessity for the knowledge of the absolute transmit power of unknown target is eliminated. The DRFG is developed by modifying the RFG in [9]. The modification is simply by the subtraction of RSS sample, in units of dB, between two sensors. The DRSS samples is obtained, so that the necessity of absolute transmit power knowledge of the unknown target is eliminated.

[3]It should be noticed that, as mentioned in [9], the geolocation techniques using RSS measurements are mainly classified into two groups: (a) pattern-recognition (fingerprinting) techniques, and (b) model-based techniques.

Hence, the proposed DRFG is able to detect the position of the unknown target, while the conventional RFG fails.

## II. System Model

The proposed DRFG is shown in Fig. 2. The FG is composed of factor nodes denoted by square and variable nodes denoted by circle as shown in Fig. 2. The factor node performs processing upon the messages coming from several variable nodes, then forwards the output messages to the destination variable node. The FG algorithm is performed in the fusion[4] center. The samples of RSS of the unknown target and of the monitoring spots measured by each sensor are sent to the fusion center. The DRSS and RSS samples of the unknown target, in units of watt, are assumed to be corrupted by zero mean Gaussian noise as in [9]. The Gaussian distribution assumption is reasonable because of the effect of accumulation of many independent factors [7], [9], including fading and shadowing variations, temporal spread due to multipath, and spatial spread.

The single static unknown (anonymous) target location is at $\mathbf{x} = [x \quad y]^T$, where $(\cdot)^T$ is transpose function. The knowledge of absolute transmit power of the unknown target is unavailable. The known position of monitoring spots are at $\mathbf{M} = [x_m \quad y_m]^T$. The function of the monitoring spots are to send the training signals with knowledge of absolute transmit power. The known sensors location are at $\mathbf{X} = [X_i \quad Y_i]^T$. The sensors measure the RSS of training signal sent from monitoring spots to create the RSS profile/pattern (fingerprints). The RSS fingerprints results are saved in database. This activity is performed during off-line period.[5] During the on-line period, the sensors measure the RSS of signal sent from the target.

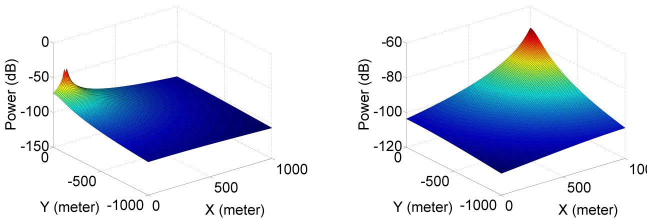
In this paper, it is assumed that the RSS samples contain only the path-loss attenuation because the environment is in an ideal scenario such as free space under line-of-sight (LOS) conditions. In the case of non LOS (NLOS) conditions, this assumption is still reasonable since the RSS samples obtained from the signals sent from the monitoring spots and the target are measured by group of sensors. For example, three sensors in Fig. 1 can be represented by three groups of sensors. The distances between sensors in a group are assumed long enough for averaging to eliminate the shadowing variations. Hence, the averaging results of a group of sensors are the samples with only path-loss component.

Both of the proposed DRFG and conventional RFG techniques can be used for position detection of the target[6] with either the only path-loss or shadowing fading condition. It depends on the size of rectangular area of four monitoring spots. The larger the size, the worse approximation obtained, hence the linear plane created by using the RSS of signal

[4]The tracking of moving target is left for future work. However, we believe that the tracking and fusion in gelocation is connected.

[5]Off-line period indicates the period before we use the proposed DRFG or conventional RFG technique position detection of the target. On-line period indicates the period when we perform position detection [9].

[6]It is a general target. However, it should be noted that the conventional RFG is unable for position detection of the unknown target.



(a) at Sensor 1. (b) at Sensor 2.

Fig. 3. RSS profile from path-loss exponent model in each sensor.

sent from the monitoring spots can approximate only path-loss component. For example, the area size is $200 \times 200$ m$^2$ or less as shown in [13]. The smaller the size, the better approximation achieved, hence the techniques can be used in shadowing variations under NLOS conditions.[7] For example, the area size is $6 \times 6$ m$^2$ in an indoor environment as shown in [9]. The relationship between the transmitted power of the target and the monitoring spots is of significant importance for this approximation.

The path-loss exponent model is used for the RSS samples as

$$P_L(d) = 20 \log \left( \frac{4\pi d_0 f_c}{c} \right) + 10n \log \left( \frac{d}{d_0} \right), \tag{1}$$

where $f_c$ is frequency carrier, $d_0$ is reference distance, $n$ is path-loss exponent, and $d$ is Euclidean distance from sensor to target or monitoring spot [13], [14]. Figs. 3(a)–3(b) show the RSS of path-loss exponent model with $f_c$ is 1 GHz, $d_0$ is 100 m, $n$ is 3 for urban area, and sensor positions at $(100, 0), (1100, 0), (600, -1000)$ m, however we do not show the profile of the third sensor at $(600, -1000)$ m in Fig. 1 to save the space of the paper.

The RSS sample of the unknown target and monitoring spots with path-loss attenuation is corrupted by Gaussian noise expressed as

$$\hat{P}_{w,i} = P_{w,i} + n_{w,i}, \tag{2}$$

where $\hat{P}_{w,i}$ is the RSS target sample in units of watt, $P_{w,i}$ is the true value of RSS target sample in units of watt, $n_{w,i}$ is zero-mean Gaussian noise as measurement error of the RSS samples in units of watt, and $i, i = \{1, 2, ..., N\}$, indicates primary sensor index[8].

Even though the RSS-based localization is well investigated problem, we do not use real data. Instead, in our computer simulation, $P_i$, where $P_{w,i} = 10^{P_i/10}$, is obtained from simple model, i.e., path-loss exponent model in (1). The proposed DRFG technique is also not compared with other conventional RSS-based fingerprinting techniques such as RADAR and LANDMARC.[9] These are because: (A) The conventional RFG technique in [9] has performed simulation by using both the shadowing model and real field measurement data in indoor environment scenario. (B) It is shown in [9] that the accuracy of the conventional RFG outperforms RADAR and LANDMARC. (C) The main objective of this research is to solve the problem of the conventional RFG technique in [9] for detecting the position of a single static unknown radio emitter. Hence, the comparison between the proposed DRFG and conventional RFG is sufficient to show the effectiveness of the proposed technique. (D) It is shown in the simulation results that our proposed DRFG technique outperforms the conventional RFG technique [9] when the transmit power of the unknown target is unequal to the transmit power of monitoring spots. Furthermore, given facts described above, even though the simulations utilize simple model, the proposed DRFG technique is applicable in reality.

[7]Reduction of the size of monitoring spot area to small enough size is applied to deal with shadowing variations under NLOS conditions when sufficient averaging can not be performed.

[8]We use terms primary and secondary sensor index because DRSS parameter is obtained by using subtraction operation, where RSS samples value in units of dB of the secondary sensor are subtracted from in primary sensor.

[9]RADAR is a radio-frequency (RF) based system for locating and tracking users inside buildings [15]. LANDMARC is a location sensing prototype system that uses Radio Frequency Identification (RFID) technology [16].

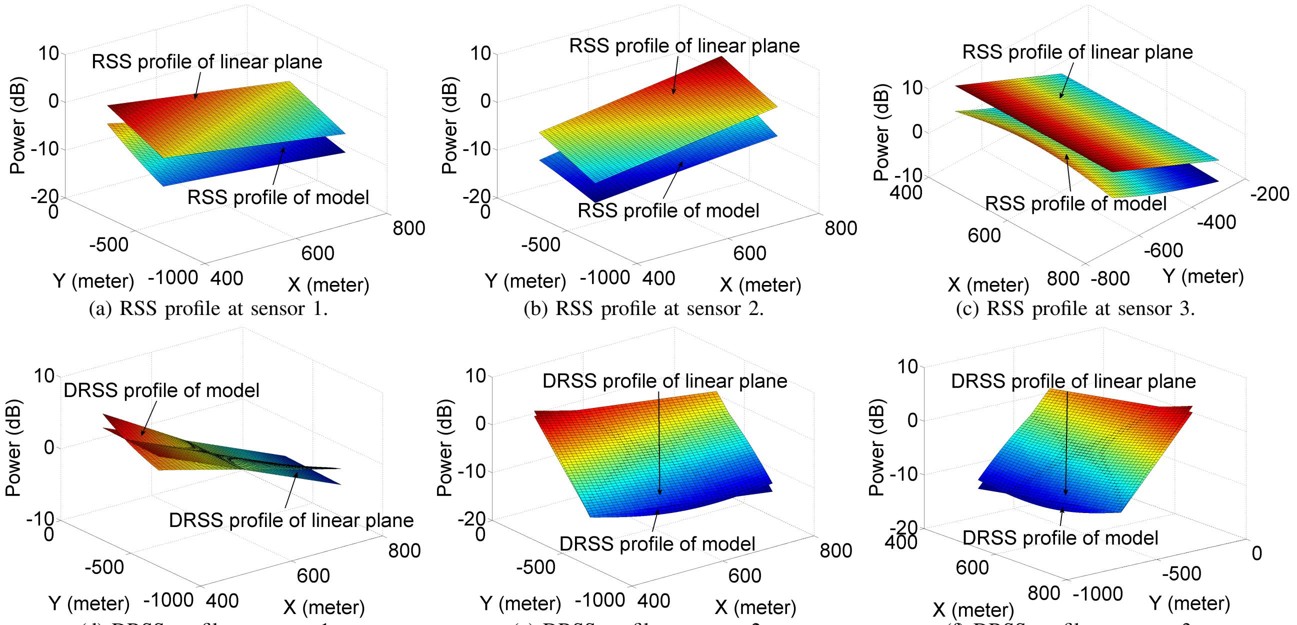
## III. Proposed DRSS-based Factor Graph Geolocation Technique

The proposed technique modifies the RFG in [9] to solve the problem of conventional RFG for estimating the location of unknown radio emitter position. The modification is simply by performing subtraction of the RSS samples between two sensors to obtain the DRSS samples as shown in Fig. 2. The subtraction of RSS sample is performed in *DRSS factor node* $B_P$. Hence, the other process after obtaining the DRSS samples follow the RFG algorithm in [9]. In this section, the RFG in [9] is summarized as the DRFG. The analysis of the DRSS profile, which eliminates the necessity of knowledge of transmit power, is also presented.

The first process in the DRFG is to receive the RSS samples, in units of watt, in *RSS measurement factor node* $C_P$. After that, the node $C_P$ converts RSS samples $\hat{P}_{w,i}$ in units of watt to $\hat{P}_i$ dB. It should be notice that the distribution of RSS samples, $\hat{P}_i$, in units of dB, shows the similarity to Gaussian distribution. Hence, the proposed DRFG and conventional RFG still preserve the Gaussianity assumption as shown in [9]. The RSS samples, $\hat{P}_i$, in units of dB, are forwarded to the *Averaged RSS variable node* $N_{P_{RSS}}$. The node $N_{P_{RSS}}$ directly forwards $\hat{P}_i$ the node $B_P$. The RSS samples in units of dB from two sensors are subtracted in the node $B_P$ resulting DRSS samples, $\hat{P}_{i,j}$, in units of dB, by performing the operation of (3), where $j, j = 2, 3, ..., N$, is the secondary sensor index. We obtain the DRSS samples derived from (2) expressed as

$$\hat{P}_{i,j} = \hat{P}_i - \hat{P}_j. \tag{3}$$

As shown in Fig. 2, there are three DRSS variables, i.e., $\hat{P}_{1,2}, \hat{P}_{1,3}$, and $\hat{P}_{2,3}$. It should be noticed that $\hat{P}_{2,3}$ is a linear combination of $\hat{P}_{1,2}$ and $\hat{P}_{1,3}$, however, $\hat{P}_{2,3}$ is not redundant. This is because $\hat{P}_{2,3}$ has different DRSS profile as shown in Fig. 4(e)–4(f). Hence, $\hat{P}_{2,3}$ is useful for detection position of the unknown target. After a set of the DRSS samples are obtained, the node $B_P$ calculates the mean and variance messages, in units of dB, and then forward the messages to the *DRSS variable node* $N_{P_{DRSS}}$. After that, node $N_{P_{DRSS}}$



(a) RSS profile at sensor 1. (b) RSS profile at sensor 2. (c) RSS profile at sensor 3.

(d) DRSS profile at sensor 1. (e) DRSS profile at sensor 2. (f) DRSS profile at sensor 3.

Fig. 4. Linear plane and model of RSS and DRSS profiles in each sensor with $\Delta P_T = 5$ dB, the sensor positions being at $(100, 0)$, $(1100, 0)$, $(600, -1000)$ m.

directly forward the messages to the *linear plane LS factor node* $A_P$. The iteration process starts from the node $A_P$.

Before the node $A_P$ is used for the iterations, the function at the node $A_P$ has to be set. The proposed DRFG technique uses the error-free DRSS of four monitoring spots to obtain the variable coefficient of the linear plane equation at the node $A_P$, expressed as [9]

$$a_{x_{i,j}} \cdot x_m + a_{y_{i,j}} \cdot y_m + a_{P_{i,j}} \cdot P_{m,i,j} = c_{m,i,j}, \tag{4}$$

where $a_{x_{i,j}}$, $a_{y_{i,j}}$ denote the coefficient of coordinate variable $x$, $y$, respectively, $x_m$ and $y_m$ denote the position coordinate of monitoring spots, where $m = 1, 2, ..., M$ is the monitoring spot index. $P_{m,i,j}$ denotes the error-free DRSS of the signal sent from monitoring spot in units of dB. The error free of the DRSS is obtained by performing averaging over large enough of the amount of DRSS samples. The large amount of the samples are collected from the DRSS measurement over long enough in time duration. $a_{P_{i,j}}$ indicates the coefficient of variable $P_{m,i,j}$. $c_{mi,j}$ indicates a constant with the value being always the unity. It is assumed, for simplicity, that the four monitoring spots are always used in the simulations so that the target is in the middle of monitoring spots. In practice, the target is not always in the middle of monitoring spots area. The RSS-based Voronoi (RSS-V) technique can be used to select the monitoring spots surrounding the target as in [10]. However, the development of the joint RSS-V and DRFG is left for future works.

Due to the values of $x_m, y_m$, and $P_{m,i,j}$ are known, hence we can utilize the least square (LS) algorithm to obtain the coefficients of linear equations at the node $A_P$. The detailed explanation of the use of LS for obtaining the coefficients of the variables $a_{x_{i,j}}, a_{y_{i,j}}$, and $a_{P_{i,j}}$, can be found in [9]. The coefficients complete the final linear equations as

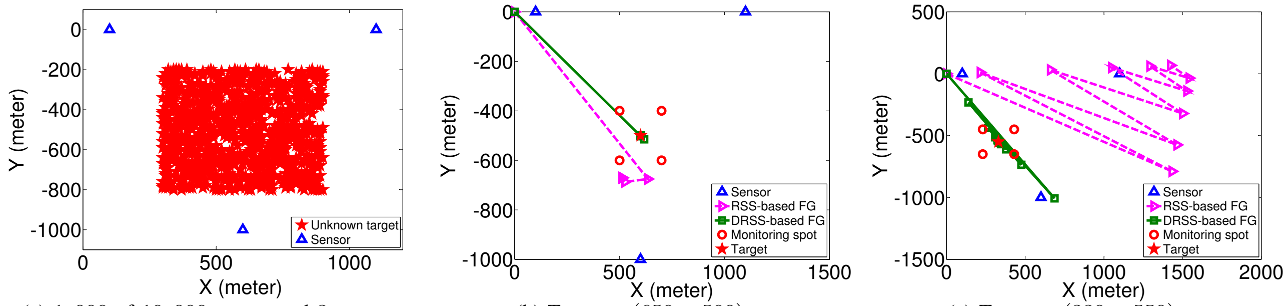
$$a_{x_{i,j}} \cdot x + a_{y_{i,j}} \cdot y + a_{P_{i,j}} \cdot P_{i,j} = c_{i,j}, \tag{5}$$

where $x$ and $y$ denotes the unknown target position, $P_{i,j}$ is the DRSS of unknown target in unit of dB, and $c_{i,j}$ is the constant with value being unity. The detail derivation formula of (5) in terms of mean and variance can be found in [9].

In this paper, we summarize the equations/operations used in this algorithm in Table. I, with the most left column being the message flow between the nodes, $h$ being general sensor index, $m$ being the mean, and $\sigma^2$ being the variance. For example, $m_x$ and $m_y$ indicates the mean values from the nodes $x$ and $y$, and $m_{\hat{P}}$ indicates the mean of the samples from measurement. The final position estimate of the unknown target emitter is taken from the mean value, $m_\Lambda$.

It is also shown in Table. I that the proposed technique requires simple arithmetic operations. As shown in [9], the computational complexity of the conventional RFG is linearly proportional to $N$. Hence, the computational complexity of the proposed technique is also linearly proportional to $N$, because the DRFG only introduces one additional subtraction operation to the conventional RFG.

We compare both the RSS the DRSS profiles at 3 sensors calculated using (1) with transmit power gap between the target and monitoring spots, $\Delta P_T$, being 5 dB. Both the approximated DRSS and RSS profiles are calculated by using (5). The simulation setup is detailed later in the Section III. As shown in Figs. 4(a) – 4(f), there are gaps between the RSS profile of path-loss mode and the approximated linear plane of RSS profile at all sensors, because there is the gap of transmit power between the unknown target and the monitoring spots. Hence, the conventional RFG fails in estimating the position of unknown radio emitter. On the contrary, the path-loss plane of DRSS has intersection with the approximated DRSS




(a) $1,000$ of $10,000$ targets and 3 sensors. (b) Target at $(650,-500)$ m. (c) Target at $(330,-550)$ m.

Fig. 5. Accuracy of the unknown target detection for many locations confirmed by the trajectory analyses with $\Delta P_T = 5$ dB.

TABLE I. THE OPERATIONS REQUIRED FOR EACH NODE IN THE PROPOSED DRFG.

| Message Flow (Nodes) | Samples ( $\hat{}$ ) and/or (Means, Variances) | | |
|---|---|---|---|
| | Inputs | Outputs | Remarks |
| $C_{P_h} \to N_{P_h}$ | $\hat{P}_{w,h},\ h=\{i,j\}$ | $\hat{P}_h,\ h=\{i,j\}$ | Similar to [7], [9] |
| $N_{P_h} \to B_{P_{i,j}}$ | $\hat{P}_h,\ h=\{i,j\}$ | $\hat{P}_h,\ h=\{i,j\}$ | New proposed |
| $B_{P_{i,j}} \to N_{P_{i,j}}$ | $\hat{P}_i$ and $\hat{P}_j$ | $\hat{P}_{i,j}=\hat{P}_i-\hat{P}_j$ and $\left(m_{\hat{P}_{i,j}},\sigma^2_{\hat{P}_{i,j}}\right)$ | New proposed |
| $N_{P_{i,j}} \to A_{P_{i,j}}$ | $\left(m_{\hat{P}_{i,j}},\sigma^2_{\hat{P}_{i,j}}\right)$ | $\left(m_{\hat{P}_{i,j}},\sigma^2_{\hat{P}_{i,j}}\right)$ | Similar to [7], [9] |
| $A_{P_{i,j}} \to x$ | $\left(m_{\hat{P}_{i,j}},\sigma^2_{\hat{P}_{i,j}}\right)$ $\left(m_{y_{i,j}},\sigma^2_{y_{i,j}}\right)$ | $((c_{i,j}-a_{y_{i,j}}m_{y_{i,j}}-a_{P_{i,j}}m_{\hat{P}_{i,j}})/a_{x_{i,j}},$ $(a^2_{y_{i,j}}\sigma^2_{y_{i,j}}+a^2_{P_{i,j}}\sigma^2_{\hat{P}_{i,j}})/a^2_{x_{i,j}}))$ | Similar to [9]; Iteration process is only performed between nodes $A_{P_{i,j}}$ and $x$, $y$. Initial values are set for $m_{x_{i,j}}$, $m_{y_{i,j}}$, $\sigma^2_{x_{i,j}}$, $\sigma^2_{y_{i,j}}$ |
| $A_{P_{i,j}} \to y$ | $\left(m_{\hat{P}_{i,j}},\sigma^2_{\hat{P}_{i,j}}\right)$ $\left(m_{x_{i,j}},\sigma^2_{x_{i,j}}\right)$ | $((c_{i,j}-a_{x_{i,j}}m_{x_{i,j}}-a_{P_{i,j}}m_{\hat{P}_{i,j}})/a_{y_{i,j}},$ $(a^2_{x_{i,j}}\sigma^2_{x_{i,j}}+a^2_{P_{i,j}}\sigma^2_{\hat{P}_{i,j}})/a^2_{y_{i,j}}))$ | |
| $x \to A_{P_{i,j}}$ $y \to A_{P_{i,j}}$ | $(m_k,\sigma^2_k)$ $k\neq l$ | $\left(\sigma^2_k\sum_{l\neq k}\frac{m_l}{\sigma^2_l},\sigma^2_k=\frac{1}{\sum_{l\neq k}\frac{1}{\sigma^2_l}}\right)$ | Similar to [7], [9]; Iteration process; For simplicity, let replace $(\cdot)_{i,j}$ to $(\cdot)_k$ |
| $x$ and $y$ | $(m_k,\sigma^2_k)$ | $\left(m_\Lambda=\sigma^2_\Lambda\sum_k\frac{m_k}{\sigma^2_k},\sigma^2_\Lambda=\frac{1}{\sum_k\frac{1}{\sigma^2_k}}\right)$ | Similar to [7], [9]; Iteration converges; For simplicity, let replace $(\cdot)_{i,j}$ to $(\cdot)_k$ |

profile around the unknown target, because the necessity of the knowledge of transmit power is eliminated by the subtraction in the node $B_P$. Hence, the DRFG successfully estimates the position of unknown target radio emitter.

## IV. SIMULATION RESULTS

To verify the performance of the proposed technique, we conducted a series of computer simulations. One target is randomly chosen from area width of $600\times600$ m$^2$ in each $10,000$ target positions performed in the computer simulations. 100 samples of RSS and DRSS are processed in 30 times of iteration for each trial. The sensors position are at $(100,0),(1100,0),(600,-1000)$ m in $(X,Y)$ coordinate, where the sensors area width is $1,000\times1,000$ m$^2$ as shown in Fig. 5(a). The root-mean-square error (RMSE) performance is evaluated by the signal-to-noise power ratio (SNR) from 0 to 45 dB. The gap of transmit power between the unknown target radio emitter and the monitoring spots is 5 dB. For simplicity, the RSS and DRSS measurements are assumed to be corrupted by the measurement error having the same variance in each sensor. The path-loss exponent model in (1) is used to create the RSS profile, where the set-up of the exponent path-loss variables are set in Section II. The monitoring spots area set in this simulation is $200\times200$ m$^2$ according to [13].

Figs. 5(b) – 5(c) show how the proposed DRFG is very accurate in detection, even though the location of the unknown target is changed many times. The accuracy is confirmed via the trajectory analysis shown in the figures. The initial point can be set from arbitrary value, however we set the initial value of nodes $x$ and $y$ at $(0,0)$ m. It is shown in Figs. 5(b) – 5(c) that the conventional RFG fails to reach the unknown target radio emitter. This is because as we discuss in Section III that the RSS profile of exponent path-loss model has a gap $\Delta P_T=5$ dB to the approximated RSS profile created by linear plane of (5). On the other hand, the trajectories of the DRFG shows that the proposed technique successfully reach the unknown target.

The Figs. 6 and 7 show that the proposed technique for any $\Delta P_T$ values is not only able to detect the location of unknown target radio emitter, but it also provides very accurate detection after it converges around 50 iterations with RMSE of around 4.5 and 3.7 m, at SNR of 10 dB and above, respectively. It is also shown that the high accuracies with RMSE of around 5 and 4 m even have been achieved in 30 and 40 iterations, respectively, at SNR of 15 dB. Hence, the proposed DRFG technique achieves high and stable accuracy for any transmit power gap values between the target and monitoring spots, but it requires more iteration.

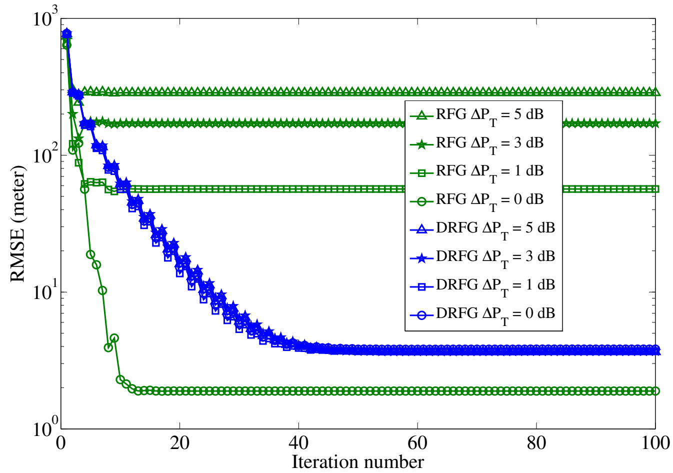



Fig. 6. RMSE vs. iteration number with $10,000$ target positions, SNR of 15 dB, and 100 samples.

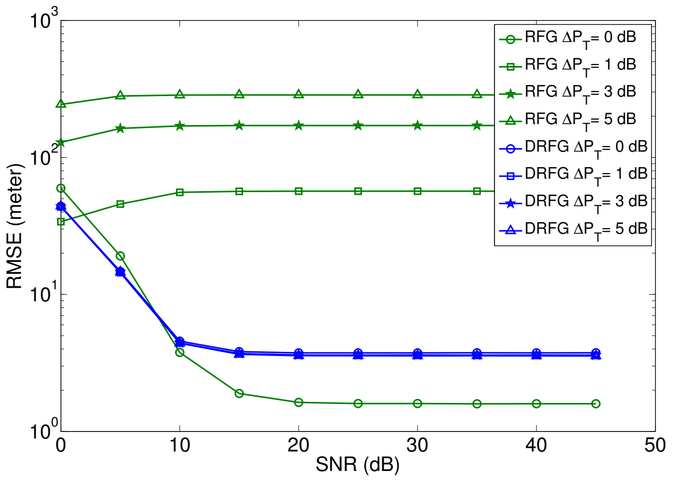



Fig. 7. RMSE vs. SNR with $10,000$ target positions, 100 samples, and 30 iterations.

On the other hand, Figs. 6 and 7 show that when the target and monitoring spots have equal transmit power, the accuracy of conventional RFG technique, with RMSE of $1.9$ and $1.6$ m, at SNR of $15$ dB and above, respectively, outperforms the proposed DRFG technique. This is because the linear plane approximation of RSS parameter has better shape than the DRSS parameter as shown in Figs. 4(a) – 4(f). However, when there are transmit power gaps, $1, 3$, and $5$ dB, the accuracy of the conventional RFG technique drop significantly to $57, 171$, and $286$ m, respectively, at SNR of $15$ dB. The performance trade-off shows that the accuracy of the proposed DRFG outperforms the conventional RFG for position detection of the unknown target, while the conventional RFG has better accuracy with having the absolute transmit power knowledge of the target. Opposite to the DRFG curve, the RFG curve shows the best accuracy in SNR of $0$ dB because the gap $5$ dB of transmit power is very big. Hence, the high noise power in $0$ dB helps the RFG for better accuracy than other SNR values even tough the overall accuracy is still low.

## V. Conclusion

The new technique of DRSS-based FG (DRFG) geolocation algorithm has been presented in this paper. It is shown in this paper that when the transmit power of target and monitoring spots are unequal, the proposed technique successfully estimates the unknown radio emitter with high accuracy around RMSE of $3.7$ m for average distance between the targets and sensors being around $664$ m, while the conventional RFG fails to detect the location of the unknown target. The transmit power information of the unknown target is no longer required because it can be replaced by performing subtraction of one sensor's RSS samples from another sensor's RSS samples. This technique provides high accuracy and low computational complexity detection, which is suitable for future geolocation technique.

## VI. Acknowledgement

This research is in part supported by Koden Electronics Co., Ltd.

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