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August 27, 2001

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Ms. Magalie R. Salas
Secretary
The Federal Communications Commission
445 12th Street S.W.
Washington, D.C. 20554

Re: CC 94-102
Ex Parte Notice

Dear Ms. Salas :

Please be advised that I have contacted the following persons on the respective dates to introduce Rosum, a new E911 technology company that intends to use terrestrial Digital Television Station signals to assist wireless carriers in Phase II compliance. Using Rosum's technology should be less costly to carriers and at the same time, be more accurate in locating handsets used for E911 calls. I have distributed a power point presentation and technical paper as well to those contacted:

8/24/01	Peter Tenhula, Senior Legal Advisor – Office of Chairman Michael Powell
8/14/01	Brian Tramont, Senior Legal Advisor – Office of Commissioner Abernathy
8/27/01	Monica Shah Desai, Legal Advisor – Office of Commissioner Martin
8/27/01	Adam Krinsky, Legal Advisor – Office of Commissioner Tristani
8/27/01	Paul Margie, Legal Advisor – Office of Commissioner Copps
8/27/01	Thomas Sugrue – Chief, Wireless Telecommunications Bureau

Sincerely,

Anita L. Wallgren

Anita L. Wallgren

Enclosures:
Rosum Power Point
Rosum White Paper

No. of Copies rec'd 0
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[redacted]

Positioning Using the ATSC Digital Television Signal

Dr. Matthew Rabinowitz, Dr. James Spilker
Rosum Corporation Whitepaper

I Overview

The technique discussed herein may be used to position cell-phones, PDAs, pagers, cars, OCDMA transmitters and a host of other devices. We make use of a signal which has excellent coverage over the United States, and the existence of which is mandated by the Federal Communication Commission. This technique requires no changes to the Digital Broadcast Stations. In order to accommodate robust indoor positioning, the signal we use has a power advantage over GPS of more than 40dB, and substantially superior geometry to that which a satellite system could provide. In order to minimize the effects of multipath, the signal has roughly six times the bandwidth of GPS. In addition, unlike GPS, the signal is not affected by transmitter Doppler or ionospheric propigation delays. Due to the high power and low duty factor of the DTV signal used for ranging, the processing requirements are minimal. The positioning technique accommodates far cheaper, lower speed, and lower power devices than a GPS technique would require. Unlike the terrestrial Angle-of-Arrival, Time-of-Arrival, and Enhanced-Time-Difference-of-Arrival positioning systems for cell-phones, this technique requires no change to the hardware of the cellular base station, and can achieve positioning accuracies on the order of 1 meter. When used to position cell-phones, the technique is independent of the air-interface, whether GSM or CDMA. A wide range of UHF frequencies has been allocated to DTV transmitters. Consequently, there is redundancy built into the system to protect against deep fades on particular frequencies due to absorption, multipath and other attenuating effects. In overview, the technology exploits the considerable Digital TV infrastructure to position wireless devices more effectively and far more economically than any current alternative.

II DTV Roll-out and Coverage

Digital Television was first implemented in the United States in 1998. As of the end of 2000, 167 stations were on the air broadcasting the DTV signal. As of February 28 2001, 1266 DTV construction permits had been acted on by the FCC commission. According the Federal Communication Commission's objective, all television transmission will soon be digital, and analog signals will be eliminated. Public broadcasting stations must be digital by May 1 2002 in order to retain their licenses. Private stations must be digital by May 1 2003. A total of over 1600 DTV stations are expected in the United States. The signal structure used for DTV is specified by the American Television Standard Committee (ATSC). Herein, we describe how the DTV signal can be used for location capability throughout the Continental United States. We describe results of tests performed in tracking the DTV signal indoors. The coverage and geometry provided by DTV stations over the Continental US (CONUS) are analyzed herein.

III Signal Description for Digital TV

The ATSC signal uses 8-ary Vestigial Sideband Modulation (8VSB). The symbol rate of the ATSC signal is f_s = 10.762237MHz which is derived from a 27.000000MHz clock. The ATSC frame appears as in Figure 1. The frame consists of a total of 626 segments, each with 832 symbols, or a total of 520832 symbols. There are two field synchronization segments in each frame, and each segment has 4

symbols used for synchronization purposes. The structure of the synchronization segment is shown in Figure 2. Notice that the two synchronization segments in a frame differ only to the extent that the middle set of 63 symbols are inverted in the second frame. The structure of the data segment is illustrated in Figure 3. Notice that the first four symbols, which are {-1, 1, 1, -1} are used for segment synchronization; the other 828 symbols carry data. Since the modulation scheme is 8-ary VSB, each symbol carries 3 bits of coded data. A rate 2/3 coding scheme is used.

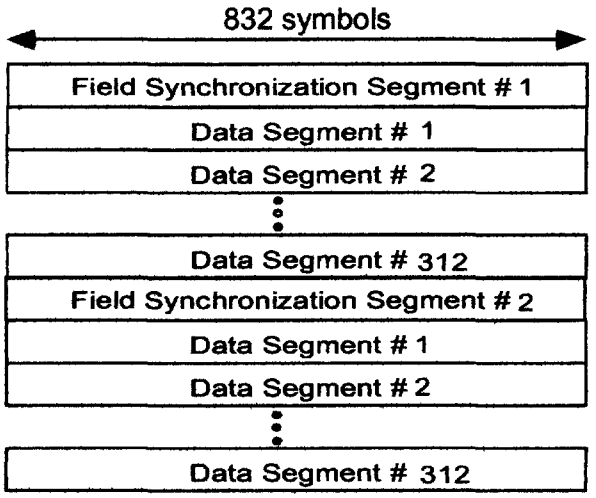

Figure 1 DTV Data Frame

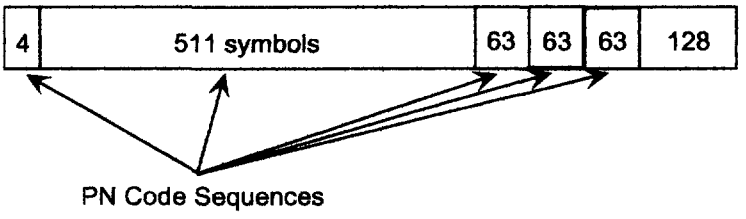

Figure 2 **DTV** Synchronization Segment in the ATSC Frame

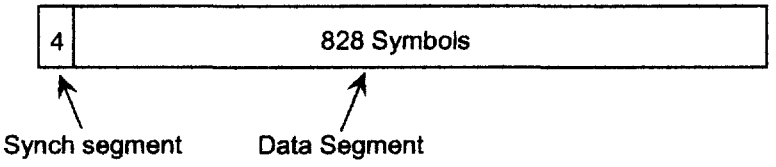

Figure 3 DTV Data Segment in the ATSC frame

The 8VSB signal is constructed by filtering. The in-phase segment of the symbol pulse has a raised-cosine characteristic [3]. The pulse can be described as:

$$p(t) = sinc\left(\frac{\pi t}{T}\right)\frac{\cos\left(\frac{\pi\beta t}{T}\right)}{1-\frac{4\beta^2 t^2}{T^2}} \tag{1}$$

Where $\beta = 0.05762$. This signal has a frequency characteristic:

$$P(f) = \begin{cases} T & ;0 \le |f| < \frac{1-\beta}{2T} \\ \frac{T}{2}\left\{1+\cos\left[\frac{\pi T}{\beta}\left(|f|-\frac{1-\beta}{2T}\right)\right]\right\} & ;\frac{1-\beta}{2T} \le |f| \le \frac{1+\beta}{2T} \\ 0 & ;|f| > \frac{1+\beta}{2T} \end{cases} \tag{2}$$

From which we see that the one-sided bandwidth of the signal is $(1+\beta) = 5.38\text{MHz} + 0.31\text{MHz}$. In order to create a VSB signal from this in-phase pulse, the signal is filtered so that only a small portion of the lower sideband remains. This filtering can be described as:

$$P_v(f) = P(f)(U(f) - H_\alpha(f)) \tag{3}$$

$$U(f) = \begin{Bmatrix} 1, f \ge 0 \\ 0, f < 0 \end{Bmatrix} \tag{4}$$

where $H_\alpha(f)$ is a filter designed to leave a *vestigial* remainder of the lower sideband. A plot of the gain function for $H_\alpha(f)$ is shown in Figure 4. . The filter satisfies the characteristics:
$H_\alpha(-f) = -H_\alpha(f)$ and $H_\alpha(f) = 0, f > \alpha$

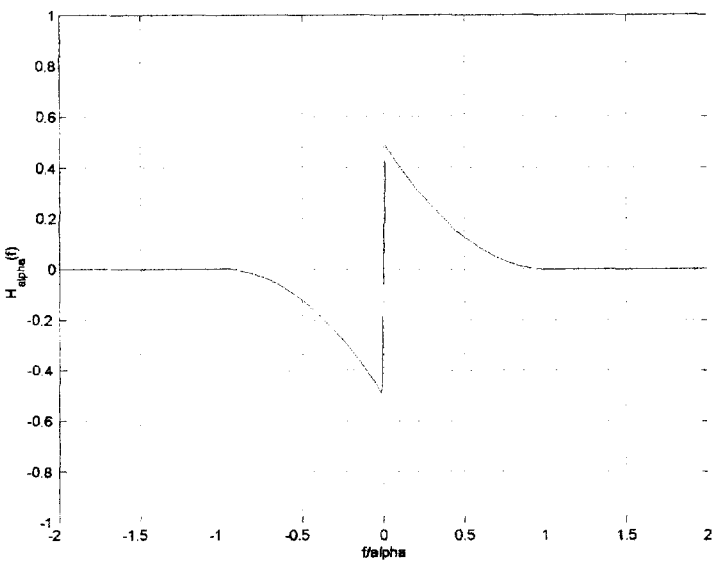

Figure 4 Transfer function of the filter H_α

The response $U(f)P(f)$ can be represented as

$$U(f)P(f) = \frac{1}{2}(P(f) + j\breve{P}(f)) \tag{5}$$

Where $\breve{P}(f) = -j\,\mathrm{sgn}(f)P(f)$ is the Hilbert transform of $P(f)$. The VSB pulse may be represented as

$$P_v(f) = \frac{1}{2}X(f) + \frac{j}{2}(\breve{X}(f) + 2X(f)H_\alpha(f)) \tag{6}$$

and the baseband pulse signal

$$p_v(t) = \frac{1}{2}x(t) + \frac{j}{2}(\breve{x}(t) + x_\alpha(t)) = p_{vi}(t) + jp_{vq}(t) \tag{7}$$

where $p_{vi}(t)$ is the in-phase component, $p_{vq}(t)$ is the quadrature component, and

$$x_\alpha(t) = 2\int_{-\infty}^{\infty} X(f)H_\alpha(f)e^{j2\pi ft}df \tag{8}$$

Before the data is transmitted, the ATSC signal also embeds a carrier signal, which has -11.5dB less power than the data signal. This carrier aids in coherent demodulation of the signal. Consequently, the transmitted signal can be represented as:

$$s(t) = \sum_n C_n \{ p_{vi}(t - nT)\cos(\omega t) - p_{vq}(t - nT)\sin(\omega t) \} + A\sin(\omega t) \quad (9)$$

Where C_n is the 8-level data signal.

IV Tracking the DTV Signal

We will discuss three different techniques of tracking the DTV signal. It should be realized that many other techniques exist for tracking the DTV signal; however, we describe only some of the canonical approaches herein. Further discussion of the some standard tracking techniques is provided in **[1]** and **[2]**. We do not describe herein how the receiver architecture can be optimized for the structure of DTV synchronization signals, since that is overly detailed for the scope of this white paper. Suffice to say, if all processing is implemented in firmware, the duration of a pseudorange measurement for one DTV channel has an expected value of 23ms on a low-power, low-cost off-the-shelf DSP.

IV. A Software Receiver

The most thorough approach to mitigating the effects of multipath is to sample an entire autocorrelation function, rather than to use only early and late samples as in a hardware setup. In the case that position can be computed with a brief delay, such as in E911 applications, the simplest approach is to use a *software receiver*, which samples a sequence of the filtered signal, and then processes this in firmware on a DSP. Figure 5 displays a typical architecture for tracking in software. The phase-locked loop implements a narrowband filter to extract the carrier from the signal. The signal is then downconverted by mixing with the carrier signal; the baseband signal is emitted from the filter. The receiver can also be implemented with multiple downconversions for ease of implementing the noise filters. In addition, the receiver need not downconvert the signal to baseband before sampling. Downconversion may be implemented by undersampling the bandpass filtered signal.

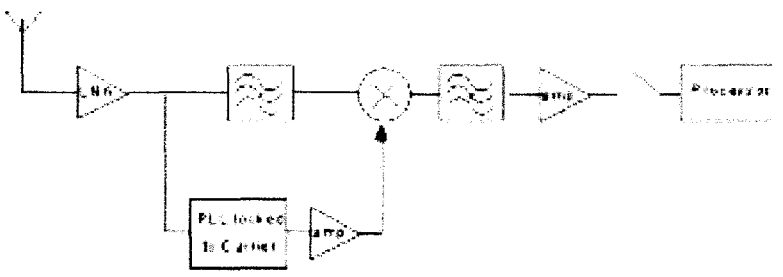

Figure 5: Architecture for the Software Receiver

We will describe here a software receiver approach that assumes nominal offset frequency for the downconverted sampled signal. For the method of Figure 5 where the signal is converted directly to baseband, the nominal offset is 0Hz. This algorithm describes how the complete autocorrelation function can be generated, in a software receiver, based on samples of a signal $s(t)$. This algorithm may be implemented far more efficiently for the low duty factor signal. Let T_i be the period of data sampled, ω_{in} be the nominal offset of the sampled incident signal, and let ω_{offset} be the largest possible offset frequency, due to Doppler shift and oscillator frequency drift.

- $R_{max} = 0$
- Create a complex code signal

$$s_{code}(t) = \sum \overline{C}_n \{p_{vi}(t - nT) + jp_{vq}(t - nT)\}$$

where $\overline{C}_n$ is zero for all symbols corresponding to data signals and non-zero for all symbols corresponding to synchronization signals.

- For $\omega = \omega_{in} - \omega_{offset}$ to $\omega_{in} + \omega_{offset}$ step $0.5\frac{\pi}{T_i}$
  - Create a complex mixing signal

    $s_{mix}(t) = \cos(\omega t) + j\sin(\omega t), t = [0...T_i]$
  - Combine the incident signal $s(t)$ and the mixing signal $s_{mix}(t)$

    $s_{comb}(t) = s(t)s_{mix}(t)$
  - Compute the correlation function $R(\tau) = s_{code} * s_{comb}(\tau)$
  - If $\max_\tau |R(\tau)| > R_{\max}$,

    $R_{\max} \leftarrow \max_\tau |R(\tau)|, R_{store}(\tau) = R(\tau)$
- Next ω

Upon exit from the process, $R_{store}(\tau)$ will store the correlation between the incident signal $s(t)$ and the complex code signal $s_{code}(t)$. $R_{store}(\tau)$ may be further refined by searching over smaller steps of ω. The initial step size for ω must be less than half the Nyquist rate $\frac{2\pi}{T_i}$.

IV. B Hardware Receiver

Figure 6 displays the architecture for a Maximum Likelihood (ML) receiver that may be implemented in hardware. This receiver employs a decision-directed architecture. Namely, the actual data symbols $\{C_n\}$ must be determined in the receiver, or must be known a-priori, as in the case of the ATSC synchronization codes. It should be understood that many different versions of, and approximations to, this architecture may be implemented without changing the essential idea. We assume, as above, that the receiver first locks onto the injected carrier signal for coherent modulation. This is not necessary; receivers can be implemented which simultaneously determine symbol synchronization and carrier phase [3]. The signal is coherently downconverted to produce both an in-phase and quadrature component. These components are then passed through a matched filter, which are respectively the in-phase and quadrature symbols reversed in time. The signal is then differentiated, and sampled at the times $nT + \hat{\tau}$ where $\hat{\tau}$ is the current estimate of the time offset necessary for synchronization. The sampled signal is then mixed with the known data sequence $\{\overline{C}_n\}$ Since the Phase-Locked-Loop (PLL) bandwidths required for navigation are small compared with those required for DTV reception, we do not assume demodulation and detection of the DTV data symbols. Consequently, as discussed above, $\{\overline{C}_n\}$ is 0 except where the symbol corresponds to a known synchronization symbol. The in-phase and quadrature samples are then input to the summation filters. If $\hat{\tau}$ is the ML estimate, then the outputs of the summations should be 0. The purpose of the control loop is to drive the outputs of the summation devices to 0. The control law combines the in-phase and quadrature outputs, and may also filter the information, to drive the NCO so that the outputs of the summation devices go to 0. The summation devices will sum over a number of symbols consistent with the update rate of the loop. The NCO also drives the code generator, so that the code symbols $\overline{C}_n$ are aligned with the incident signal.

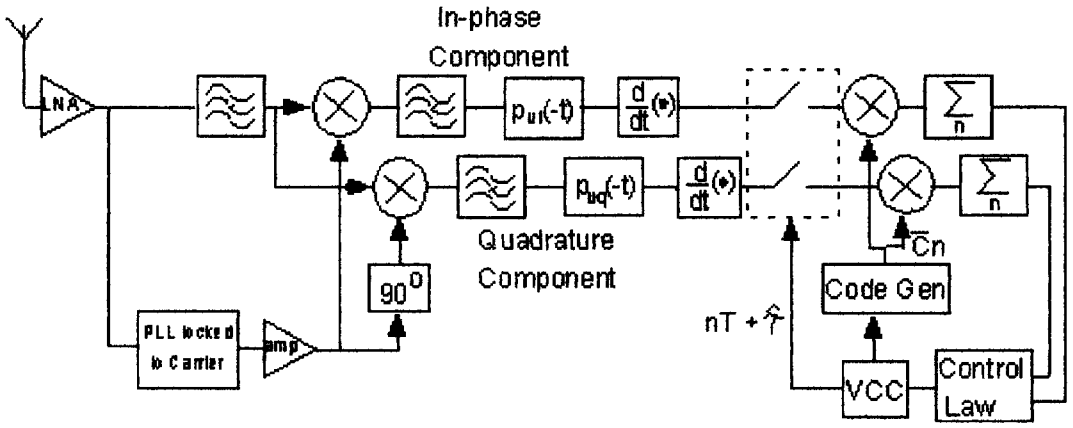

Figure 6: Architecture for a ML Decision-Directed Receiver

There are many other ways of implemented hardware code tracking and synchronization **[4]** such as with the use of Early-Minus-Late Power Discriminators, Dot-Product Discriminators, and the Coherent Early-Minus Late Discriminator.

While we have only discussed the tracking mode of the receiver, another mode is required for signal acquisition. In the case of the DTV signal, the initial acquisition search can be broken into two parts. The first is a search for the 4 synchronization symbols on each data segment, or a search over 832 chips. This is followed by a search for the Field-Synch Segment, or a search over 313 chips (if the middle 63-chip PN sequence is ignored). This can be achieved very quickly. In addition, while this receiver makes use of both in-phase and quadrature symbols, simpler techniques may make use of only the in-phase or quadrature components. Such techniques may have desirable properties for multipath rejection.

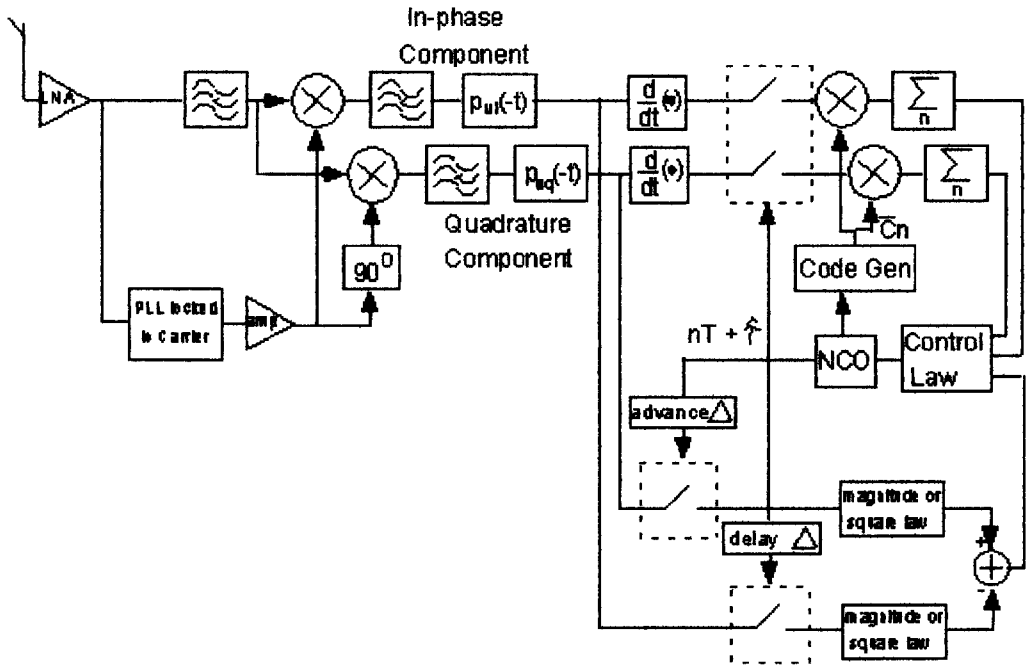

Figure 7: Architecture for a Decision Directed Receiver Combined with a Non-Decision-Directed Receiver

The receivers described above only use the synchronization chips in order to update the estimate $\hat{\tau}$. However, there are other techniques which may be used for resolving $\hat{\tau}$ using the data symbols as well as the synchronization symbols, in a non-decision directed architecture. Such a method is illustrated in figure 7. Note that this technique combines the correlator technique, which only makes use of the synchronization symbols, with a non-decision-directed approach that uses an early-late gate synchronizer. The latter can also update $\hat{\tau}$ based on the data symbols, since it doesn't require knowledge of the symbols to implement the tracking loop. The control law would combine the inputs from the coherent and non-coherent detectors, roughly in inverse proportion to the standard deviation of the timing error from each tracking loop. Of course, additional filtering can be applied to enhance tracking loop performance.

V The Navigation System

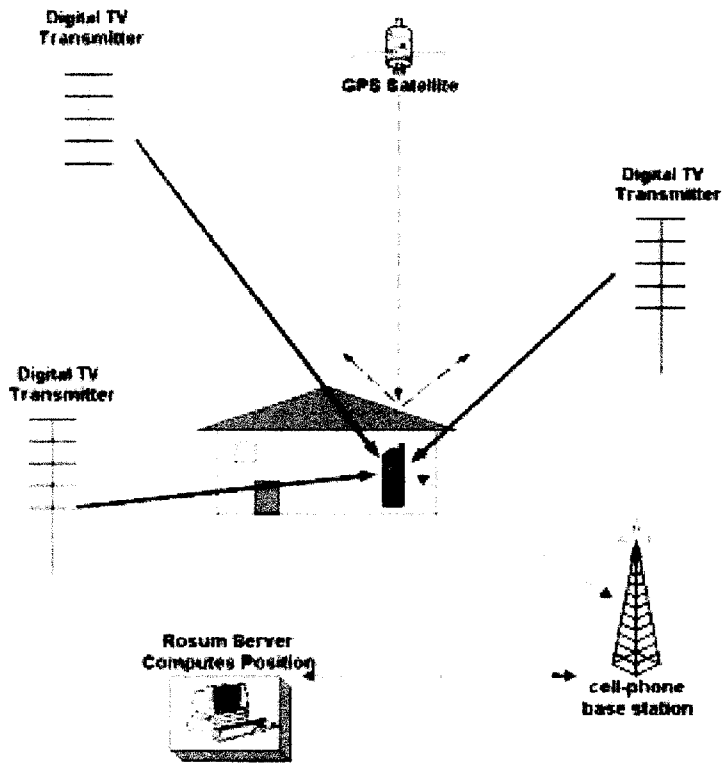

Figure 8: Architecture for positioning Digital TV transmitters

An overview of the navigation system architecture is illustrated in Figure 8. The position calculation may be implemented at the UT, or at a Processor associated with the cellular base station. Unlike the case of a satellite-based positioning technique, the location of the transmitters is unchanging, and need not be continually updated. This DTV transmitter location data may be stored at the UT or the cellular based station. By one of a variety of tracking techniques, the UT measures the pseudorange to each of the visible transmitters. Pseodoranges to three transmitters is sufficient to resolve the user's latitude, longitude, and clock bias, with sufficient accuracy to substantially exceed the FCC's phase II E911 requirements for position determination. Latitude and longitude may also be combined with an altitude map to refine the position computation. In order to compute an accurate location of the UT, the timing of the DTV synchronization code transmissions must be known.

Monitor units at known positions may be used to independently monitor the DTV station clock correction. These may be applied to the position computation at the Rosum server, or they may be transmitted to the UT for position computation. For the architecture shown, this information is maintained at the Rosum server. Alternatively, the DTV transmitters may broadcast to the UT their own clock correction, as is done for GPS satellites. Due to adjacent NTSC broadcast channels, the ATSC specification requires DTV broadcasts to be stable within 3 Hertz. To meet this requirement, most DTV broadcasts are synchronized to GPS or other stable clocks. Consequently, the DTV timing information may be updated less than once per hour, for a meter-level positioning system.

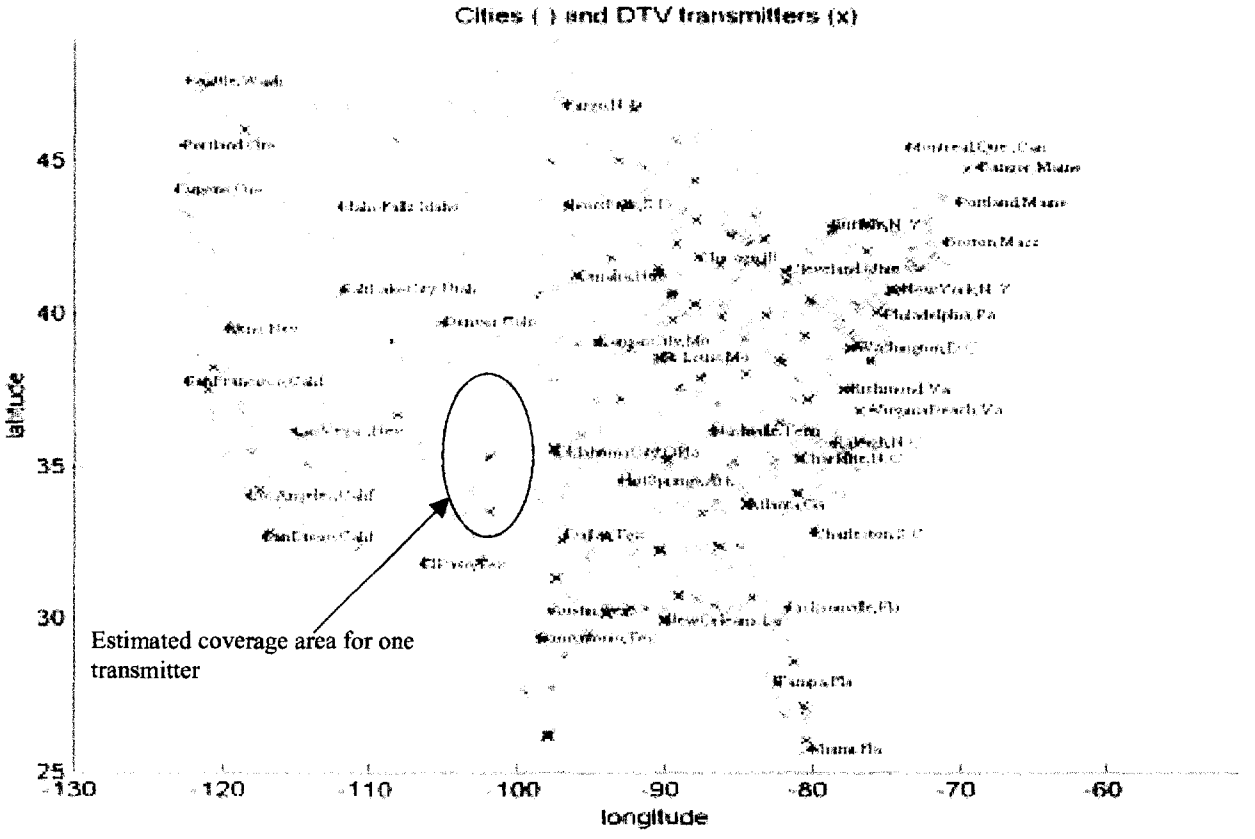

Figure 9: Locations of the first 1038 transmitters. The ring indicates the approximate coverage area of the ranging signal for one transmitter, assuming propagation according to CCIR model.

The positioning accuracy which can be achieved using this technique is determined by the Dilution of Precision (DOP) arising from the arrangement of the visible transmitters around the user terminal. Studies were conducted to analyze system performance in non-urban areas, based on those stations which were either transmitting DTV signals, or were in the process of setting up DTV capability. As of April of 2001, that amounted to roughly 1032 DTV stations. The analysis was performed based on the CCIR propagation model for signals up to 1GHz, which is conservative. The model assumes a $\frac{1}{r^2}$ power rolloff for roughly 15km, followed by a $\frac{1}{r^{5.47}}$ rolloff to the effective horizon. $d = \sqrt{\frac{8Rh}{3}}$ where R is the Earth radius and h is the height of the transmitter; then a $\frac{1}{r^{9.54}}$ power rolloff thereafter. In addition to the path loss, the link analysis assumes a polarization loss of 3dB, a matching loss in the UT of 3dB, additional attenuation loss of 20dB, and a delay-locked loop bandwidth of 5Hz. The analysis also assumes that only the synchronization PN sequences are used for ranging, which causes a 23.7dB power loss since .43% of the transmitted symbols are for synchronization. An additional power gain is realized, however, since the synchronization symbols

are, on average, higher power then the data symbols. We also assume that a loop SNR of 10dB is necessary in order to achieve an accurate pseudorange.

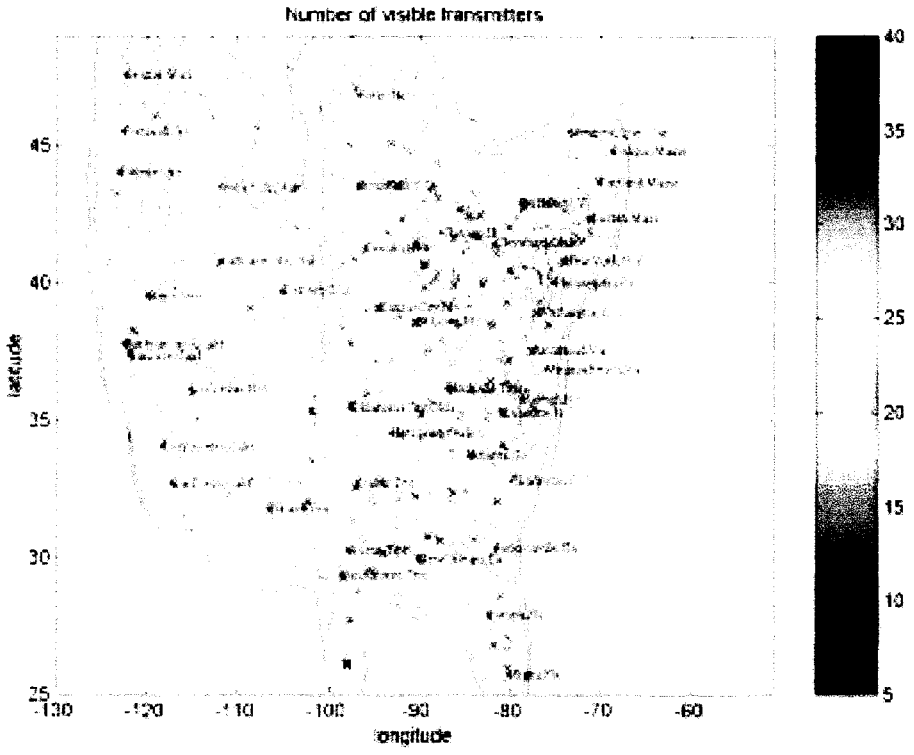

Figure 10: Contours of the number of visible UHF signals for first 1038 transmitters. Any channel for which the strongest and second-strongest signals are within 30dB of one another is dropped completely, and not used for navigation. Of course, this need not be the case.

Figure 9 displays the locations of the first 1032 DTV stations throughout the United States. Notice that the approximate coverage area of a single transmitter's ranging signal is substantially larger than the coverage area for DTV picture reception. This is due to processing gain, since precise positioning does not require reception of the DTV data. Figure 10 displays a contour map of the number of the number of transmitters visible over the CONUS, given the link assumptions discussed above. Figure 11 shows the achievable East DOP for the Continental US, for the available signals. Although multipath will dominate the noise equation, and this will vary with location, we may assume a pseudorange accuracy of roughly 1m, so the contours also roughly indicate the positioning accuracy in meters. Figure 12 illustrates the North DOP for the Continental US. Note that this DOP could be further enhanced if the clock bias of the UT is independently resolved using the cellular base stations; however, as can be clearly seen from the figures, this does not appear to be necessary.

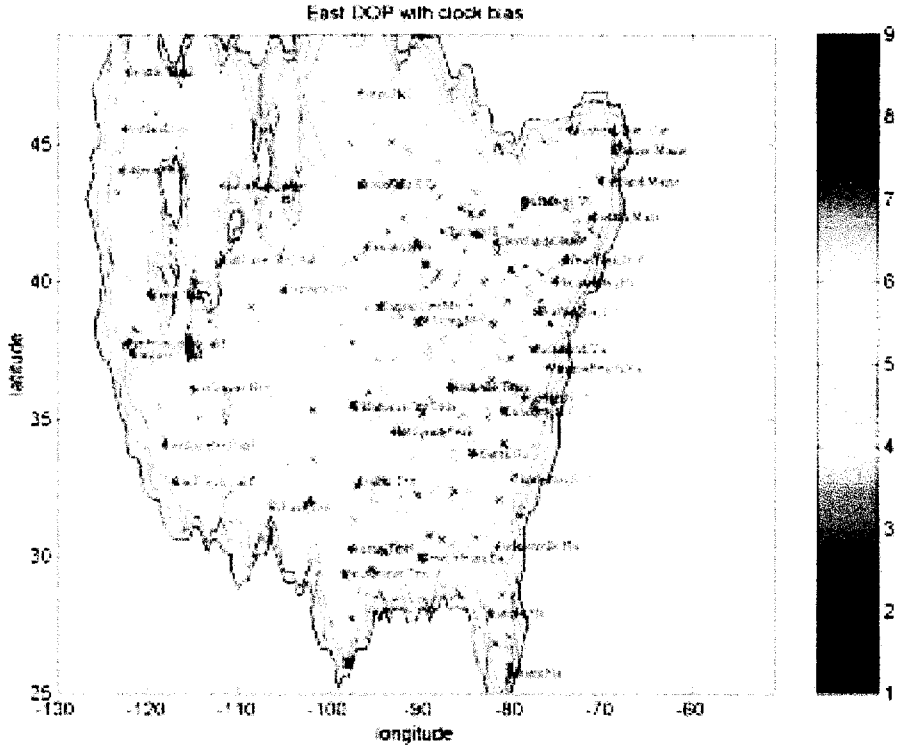

Figure 11: East DOP for the first 1038 transmitters, assuming the CCIR propagation model. Only UHF signals are used, and no channel sharing is allowed.

VI Experimental Results

A technique similar to that of section IV was applied to DTV transmissions arising from San Jose, California, received indoors in Palo Alto, California. Figure 13 displays an example spectrum for a 10 *ms* sample of the signal from KICU channel 52 DTV broadcast from San Jose. The signal is downconverted to center frequency of 27MHz, or digital frequency of 0.54. The signal was digitally bandpass filtered to a bandwidth of 6MHz. The computed autocorrelation function for the in-phase and quadrature component of this signal are illustrated in Figure 14. Note that this is the autocorrelation for only the 4 synchronization symbols at the beginning of each segment. The characteristics of the signal are highlighted by figure 15. This figure displays a portion of the autocorrelation peak for the in-phase channel. From the smoothness of the curve, one can see that the signal-to-noise ratio is high. In addition, the curvature of the peak indicates the high signal bandwidth which makes this signal robust to multipath. The combination of wide signal bandwidth, high signal power, and simple signal processing result in a positioning technology more effective than any of the alternatives.

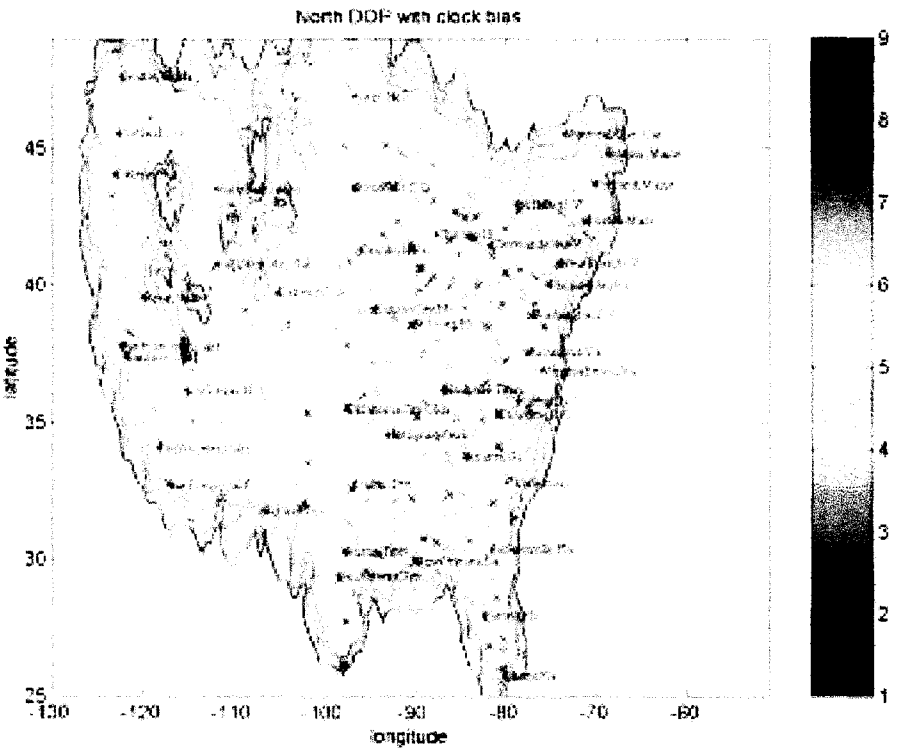

Figure 12: North DOP for the first 1038 transmitters, assuming the CCIR propagation model. Only UHF signals are used, and no channel sharing is allowed.}

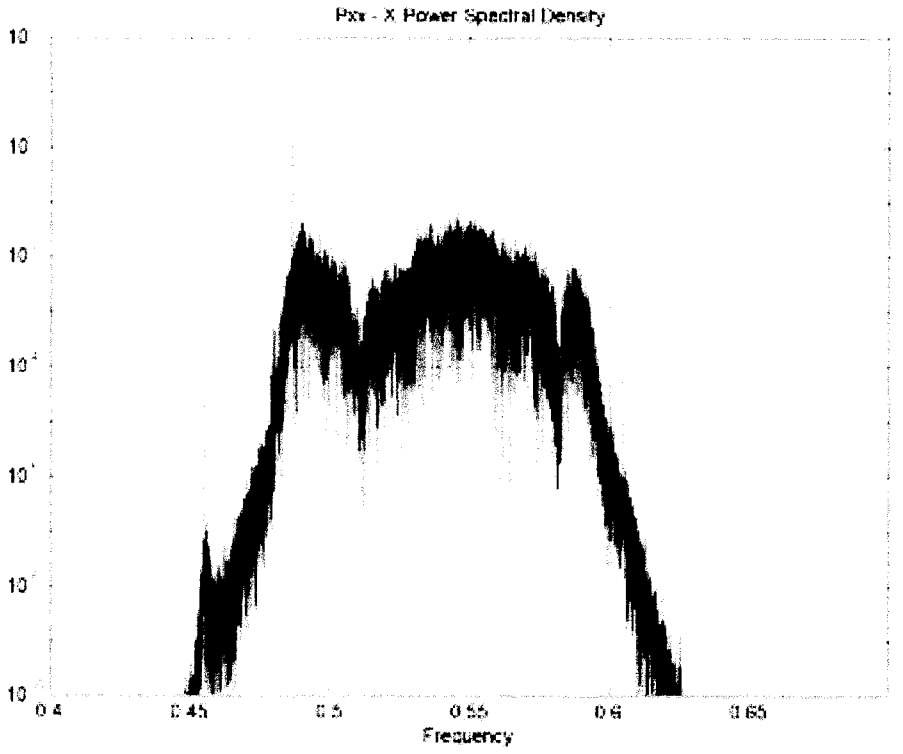

Figure 13: Spectrum of the KICU channel 52 signal after 6MHz digital bandpass filtering

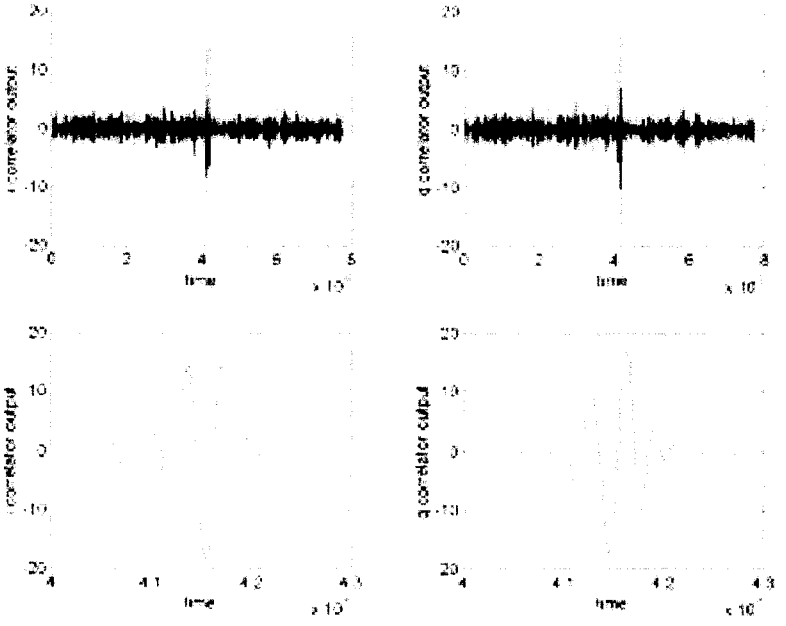

Figure 14: In-phase and Quadrature correlator outputs for 1ms of data from KICU, channel 52

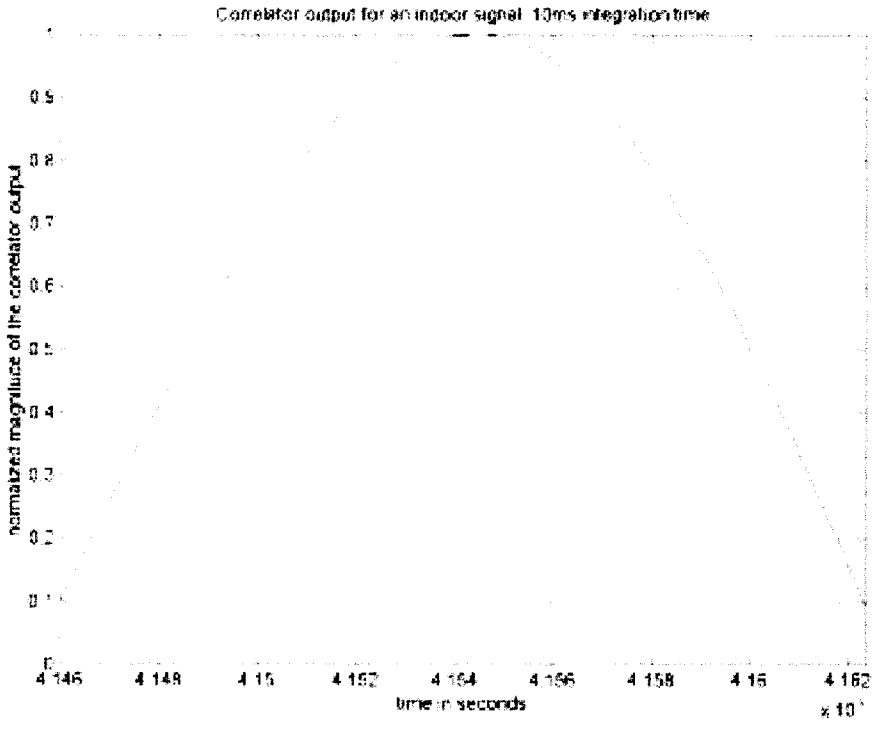

Figure 15: Section of the autocorrelation peak for 1ms of data from the in-phase signal of KICU, channel 52

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[1] J.J.Spilker Jr. Fundamentals of Signal Tracking Theory. *Global Positioning System: Theory and Applications,* pages 245-327, 1994

[2] B.W.Parkinson, M. Rabinowitz, C.E. Cohen, and J.J.Spilker Jr. Some capabilities of a joint GPS-LEO navigation system. *Proceedings of the institute of Navigation ION GPS-2000*, September 2000.

[3] J.G. Proakis. Digital Communications. McGraw-Hill, 3rd edition, 1995

[4] A.J. van Dierendonk. GPS receivers. *Global Positioning System: Theory and Applications,* Volume 1, pages329-408, 1995

Executive Summary

- Why position? E911 and Mobile Information
- Competition: Costs and Limitations
- The Rosum Solution
- Strategy Overview
- The Rosum Team
- The Future

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Why position mobile users?

FCC E911 Mandate

- Roughly 130,000 emergency calls from cell phones daily
- Every cellular service provider must be able to position cell phones

Mobile Information

- M-commerce $200 Billion market by 2004 (1)
- Location-Based Services $20 Billion by 2005 (2)
- News, Points of Interest, Museums, Directions…

Source: 1 - Strategy Analytics 2 – Ovum

[redacted]

The Competition cont...

Hybrid – Network/Handset Solutions (E-OTD, CPS)

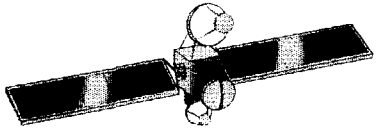
- Expensive:
  - Increase in cost-per-handset
  - Overhaul base stations
  - Hardware becomes redundant with protocol
- Ineffective:
  - Does not meet FCC requirements

Handset Solutions (A-GPS, Snaptrack)

- Expensive:
  - Increase in cost-per-handset
- Ineffective:
  - Power, processing constraints
  - Not robust indoors, in cars, in urban areas

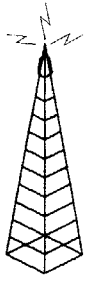
[redacted]

Synchronization Signals



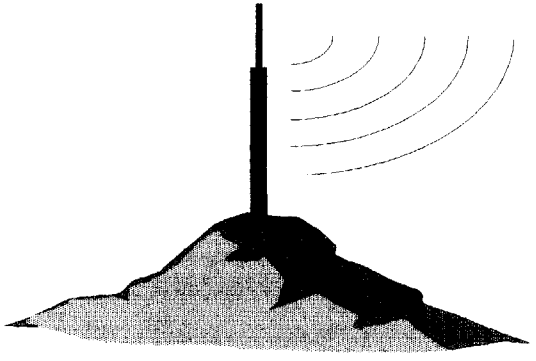
24 GPS Satellites for A GPS

- **1.6 GHz Carrier (Poor Indoor Penetration)**
- **1 MHz Bandwidth Signal**
- **1 Kwatts EIRP Transmit Power**



24,000 GSM Cell Sites for E-OTD

- **880 MHz to 915 MHz Carrier Band**
- **160 KHz Bandwidth Signal**
- **Variable power depends on cell size**



2,000 Digital TV Broadcast Stations for Rosum

- **400 MHz to 700 MHz Carrier Band**
- **6 MHz Bandwidth Signal**
- **1,000 Kwatts of Transmit Power**

[redacted]

Key Parameters

	AGPS	E-OTD	Rosum
Power (EIRP)	1 Kwatt	Variable	1,000 Kwatt
Indoor Penetration	Poor	Fair	Excellent
Accuracy	5-50 m	50-150 m	1-10 m

Competition Costs to Deploy

Network Solutions

- $25K for each of 70,000 base stations
- Must add stations as tower density is limiting

Hybrid - Network/Handset Solutions

- $10K per station for at least 67% of stations
- $5 per handset in addition to network costs

Handset solutions

- $33 per handset according to handset manufacturers

Source: Forrester Report "Capitalizing on Mobile Location", May 2001

[redacted]

The Competition

Network Solutions (TDOA, AOA, Allen Telecom)

Expensive:

- Overhaul existing base stations and build new ones
- Hardware becomes redundant with changes in protocol

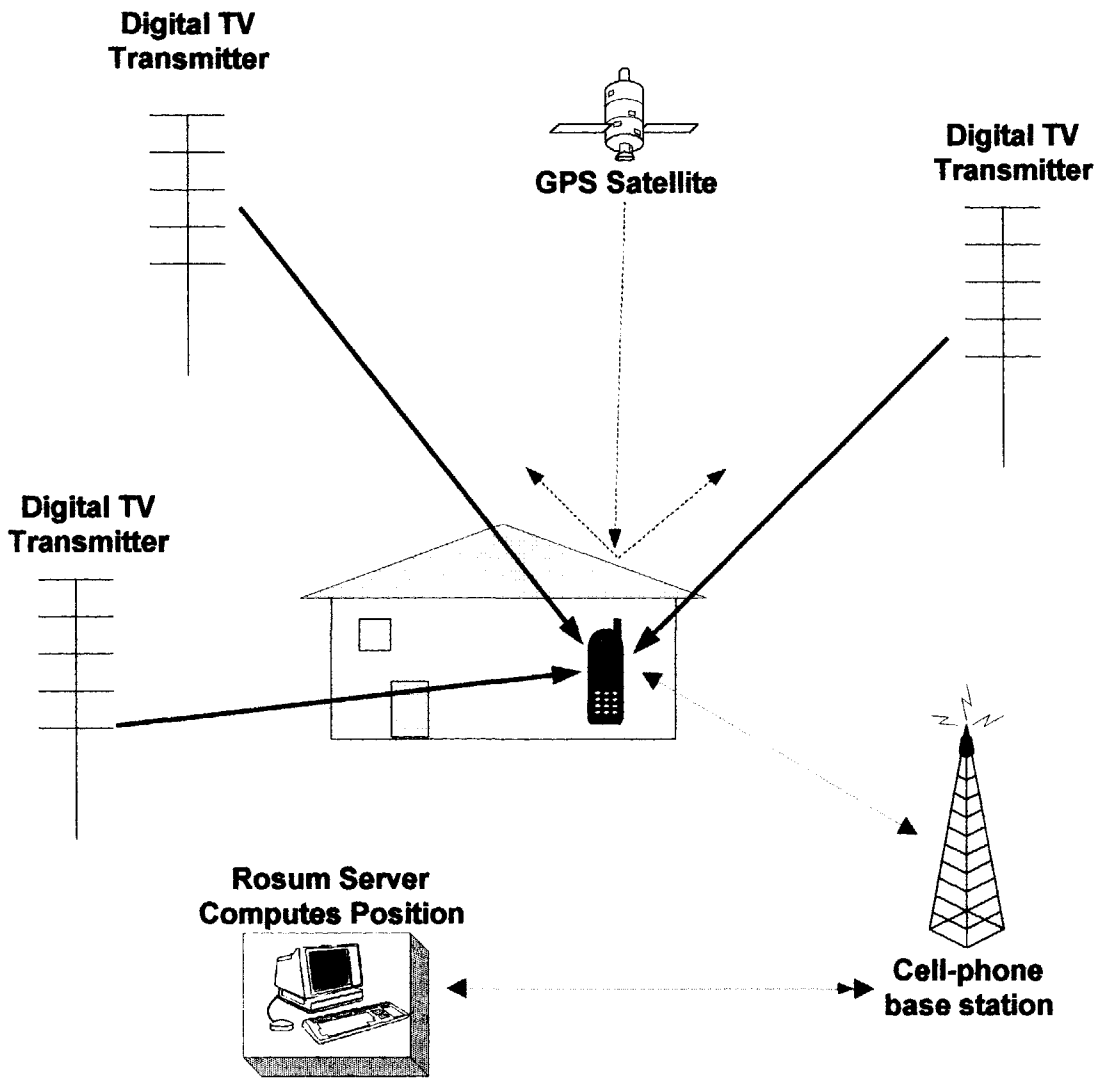
Ineffective:

- Does not work indoors
- Poor coverage in rural areas
- Does not meet FCC requirements

[redacted] The Solution - Digital Television

- Very high-power (several Megawatts)
- Embedded synchronization signal
- 6MHz bandwidth for precise ranging
- Better geometry than GPS
- No ionosphere, no transmitter Doppler
- Prime UHF spectrum
- 1600+ DTV Stations will be online

The Solution – Rosum Technology



The Solution – Rosum Technology

Simple System Architecture = Low cost

- Signal processing less than $5 per handset
- Simple server requirements
- No base station changes

High powered DTV signal = Robust positioning

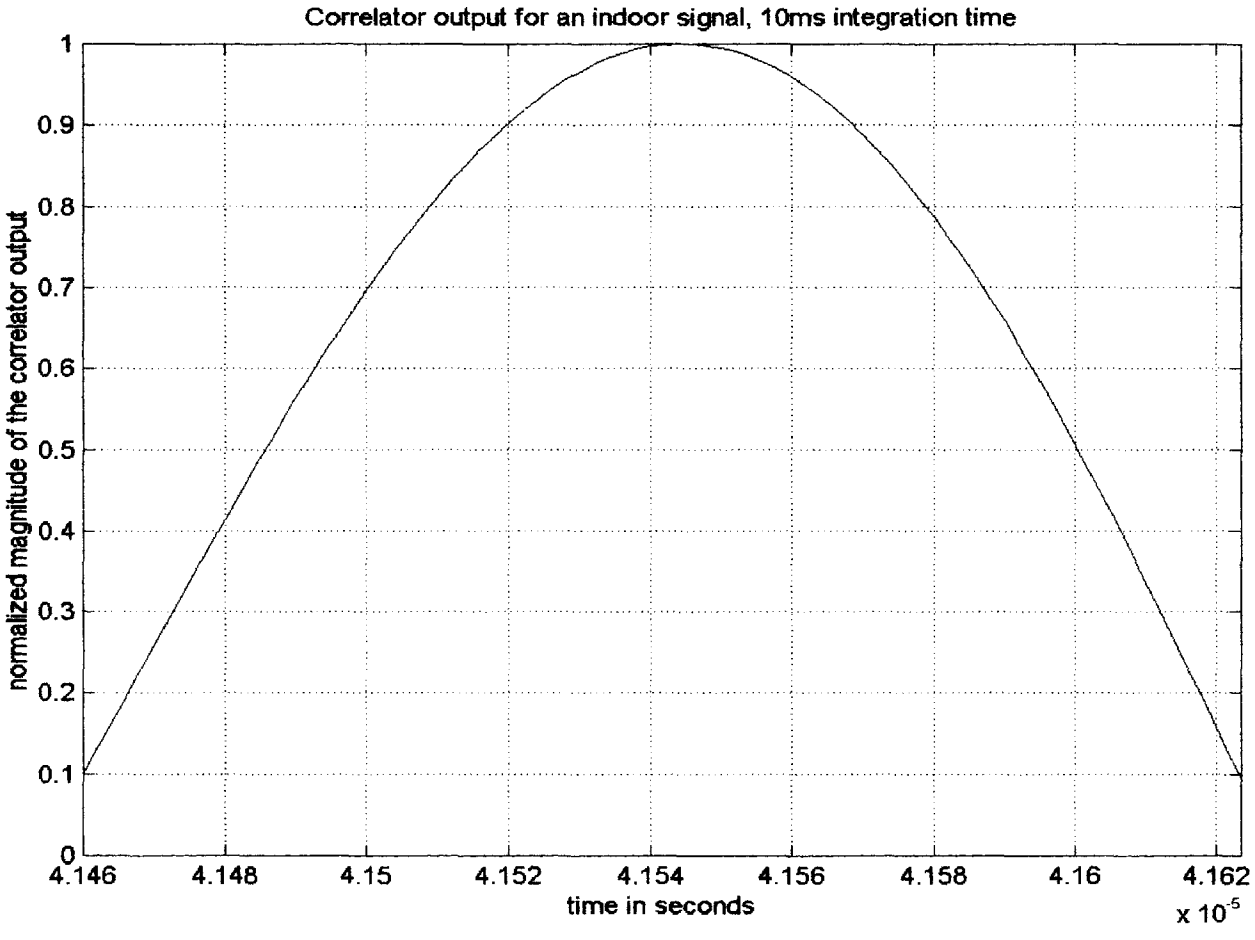
- Ubiquitous coverage indoors and out
- Meter level positioning with low GDOP

High Accuracy = Additional applications

- Driving Directions, Location-Based Information, Merchant Search, Mom Market, Mobile Instant Messaging, Inventory Tracking

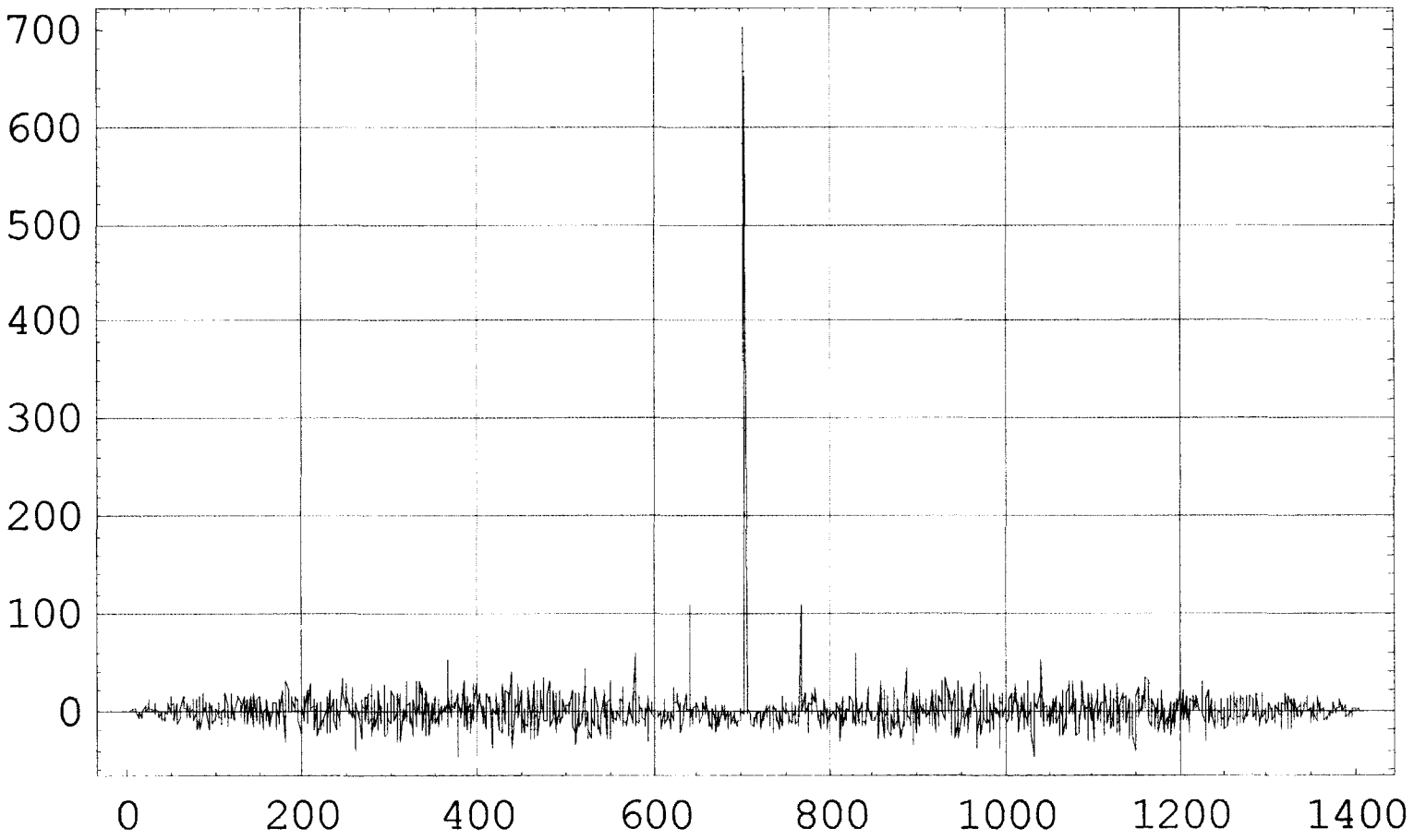
[redacted]

Robust Signal: High SNR, Wide Bandwidth



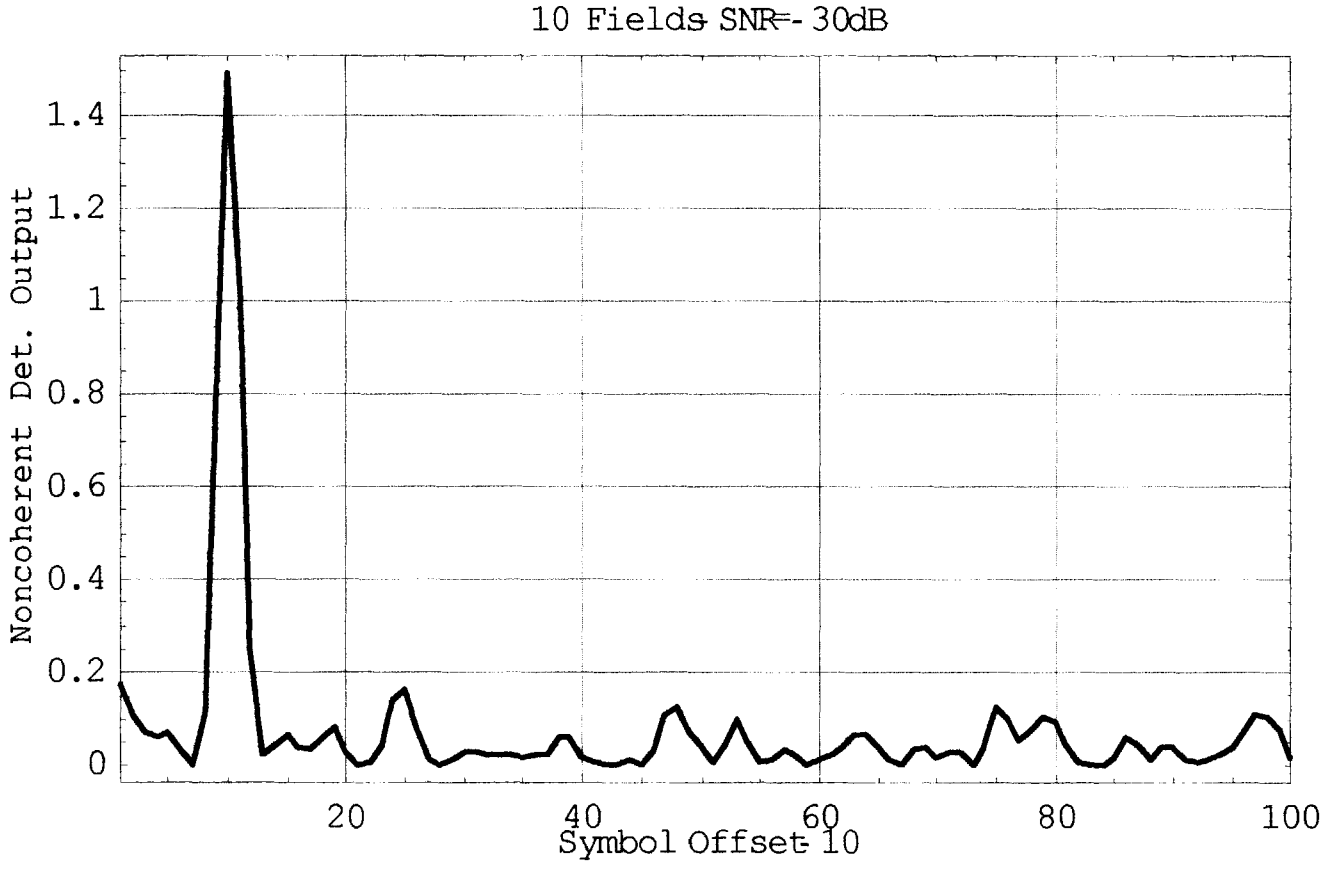
[redacted]

Simple Signal Processing: Auto-correlation of Segment Synch

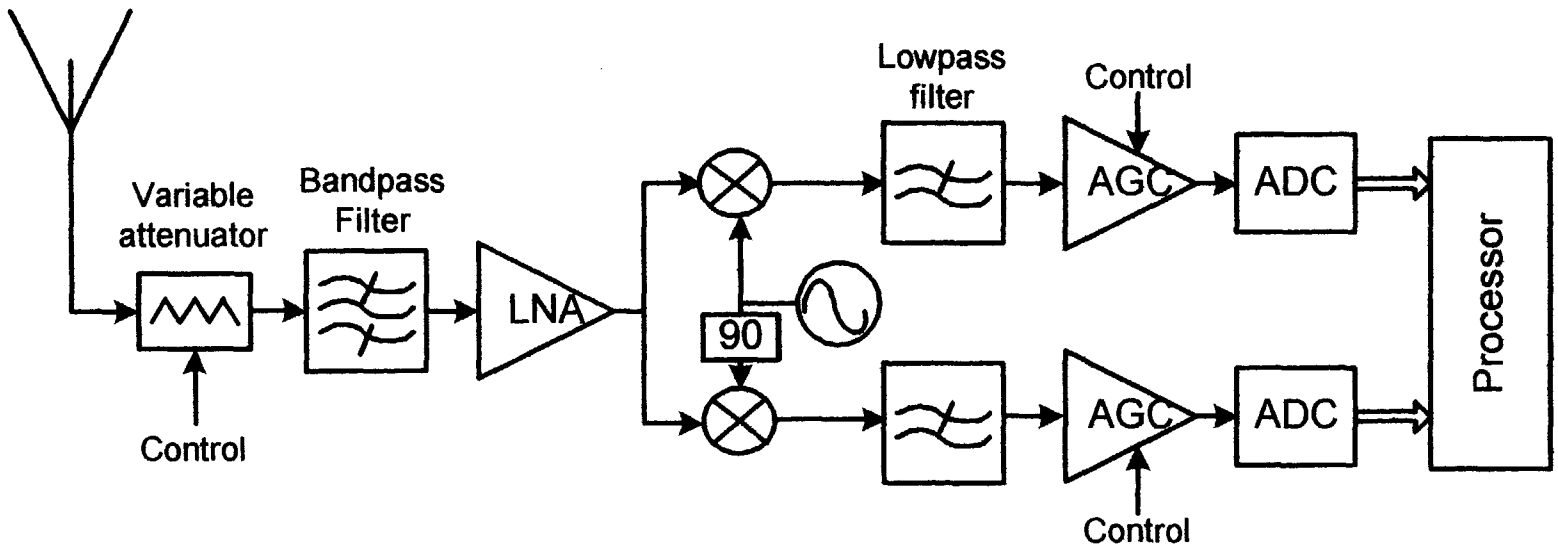


[redacted]

Non-Coherent Correlation of 242ms: -27dB SNR in 6 MHz BW



Simple Front End Architecture for VLSI Integration



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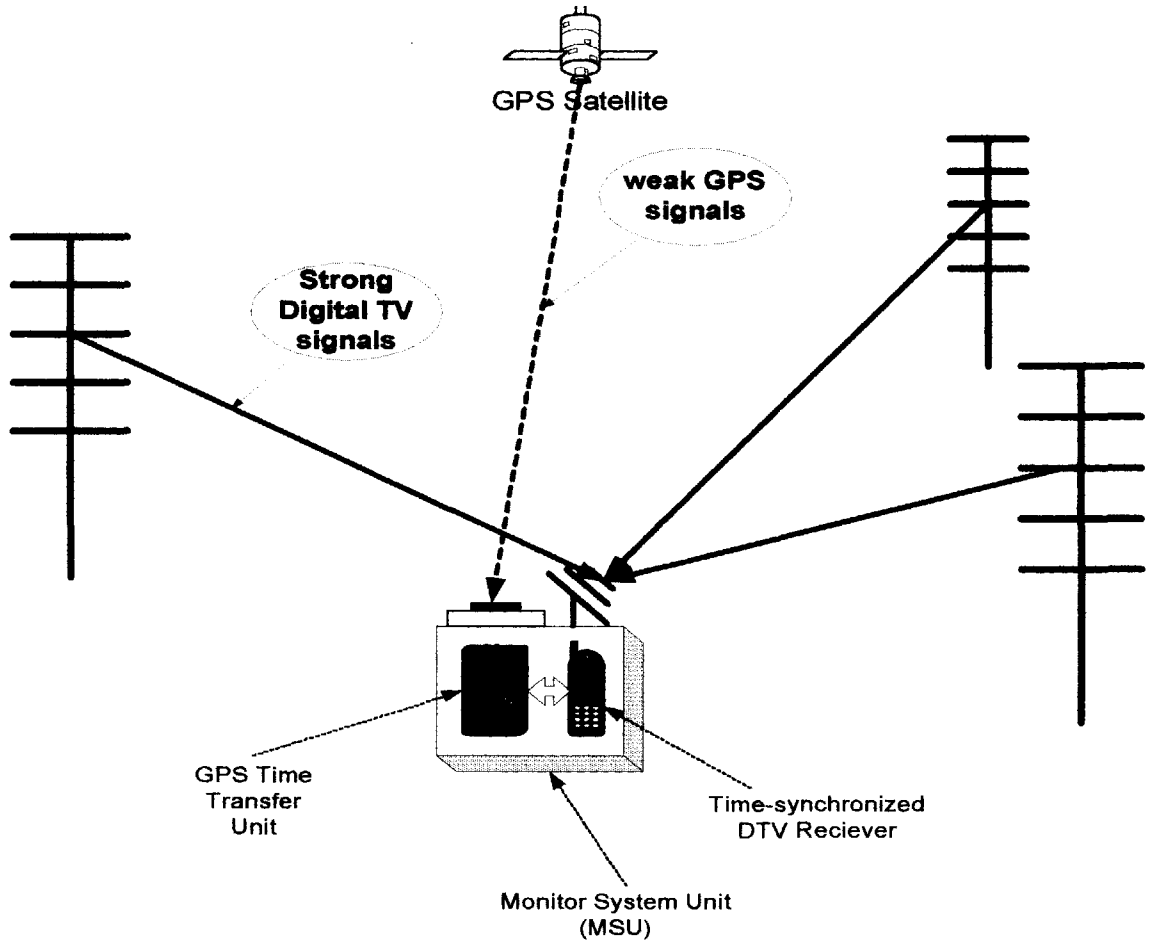
Monitor System Unit



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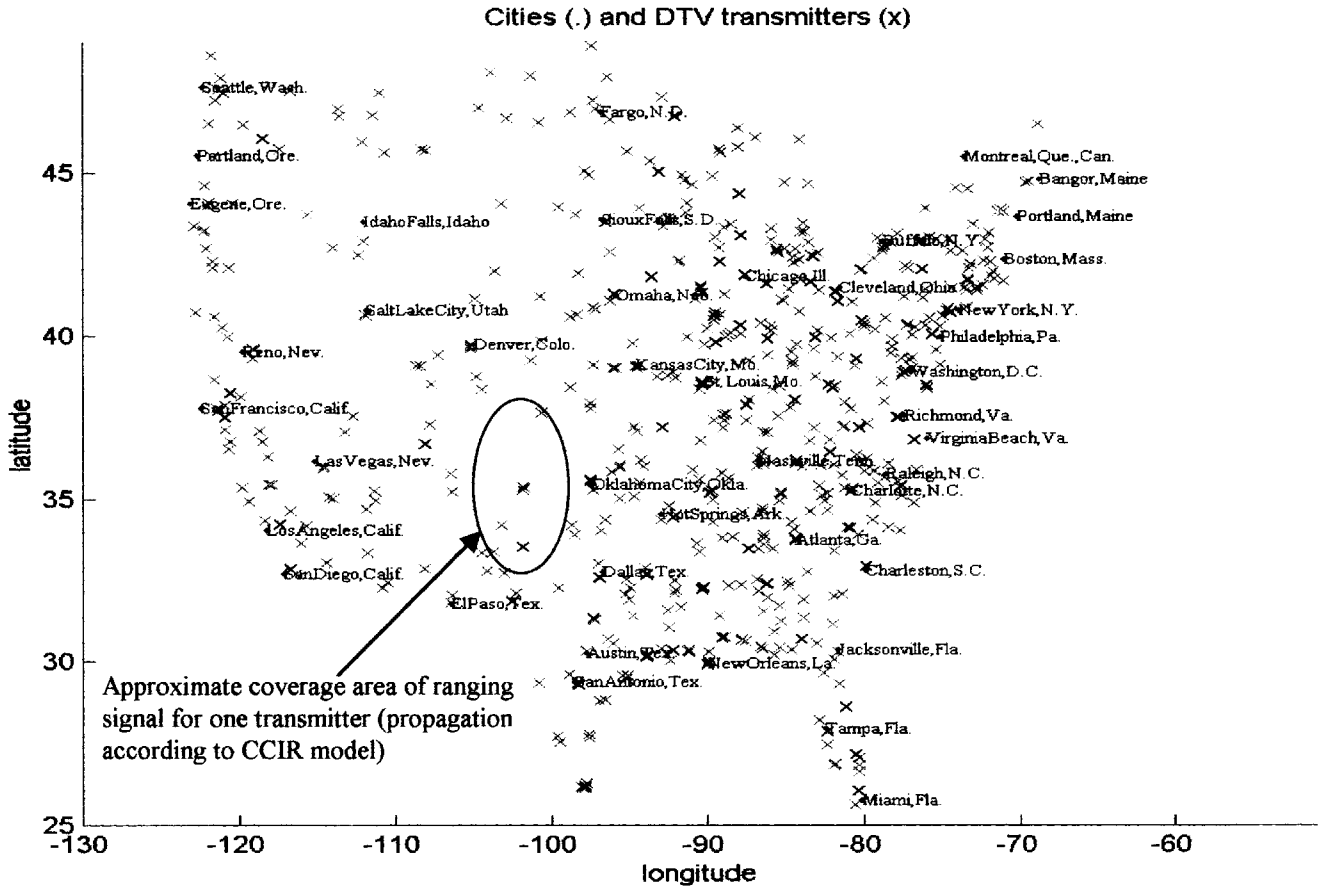
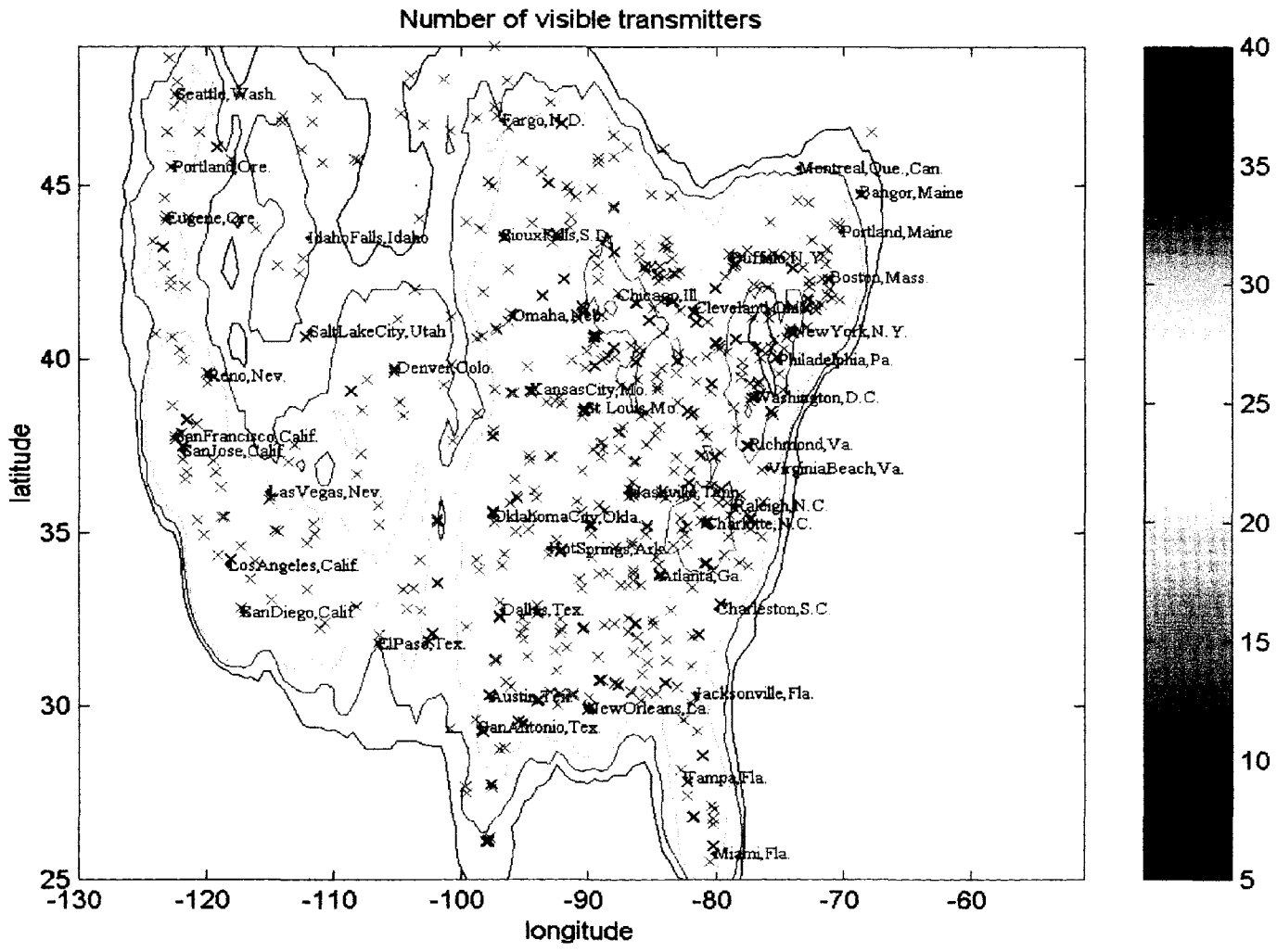
The First 1038 Transmitters



Contours of the Number of Visible UHF Signals for First 1038 Transmitters. (Assumptions in Text Below)



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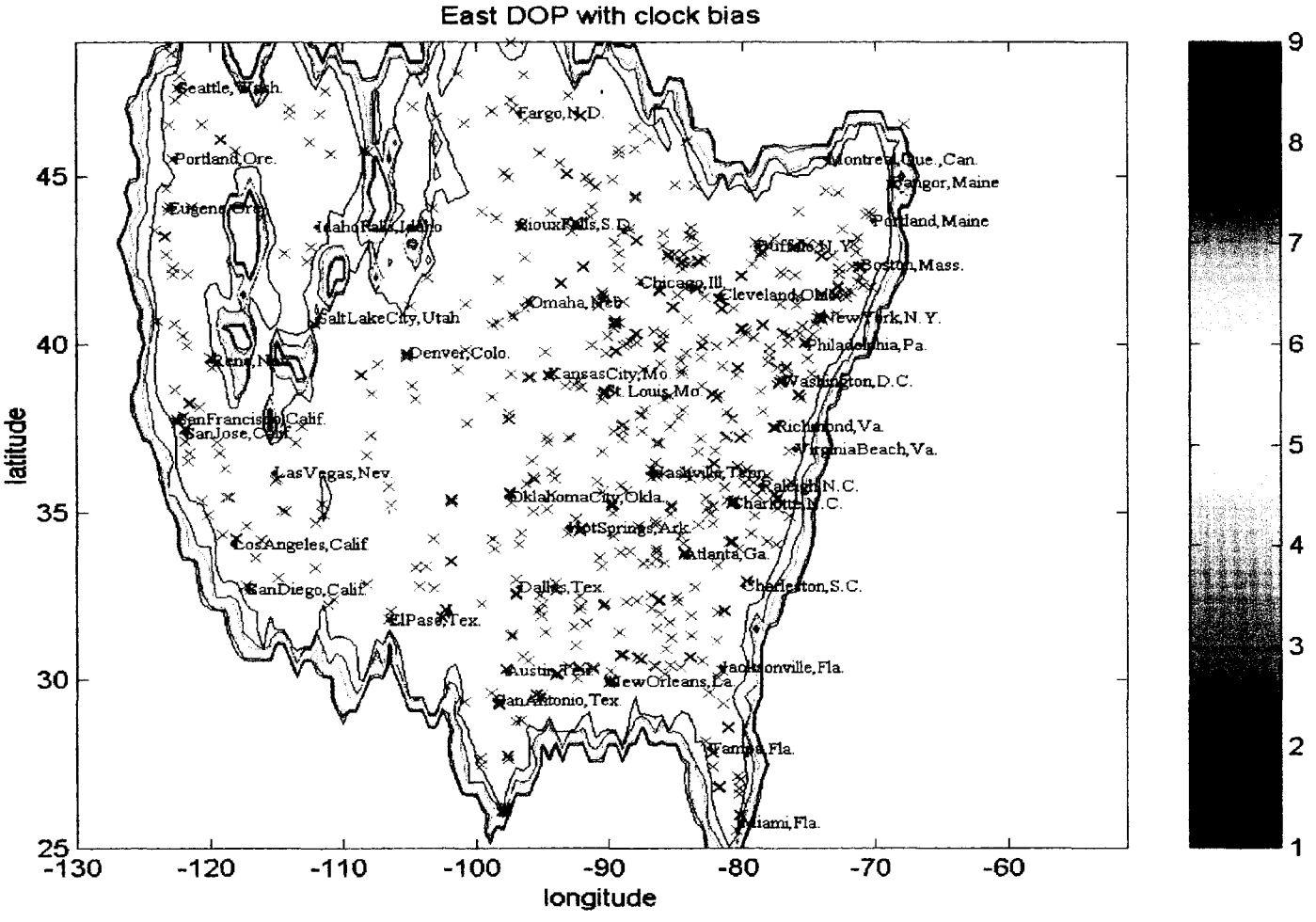
East DOP for 1038 Transmitters, UHF, No Channel Sharing



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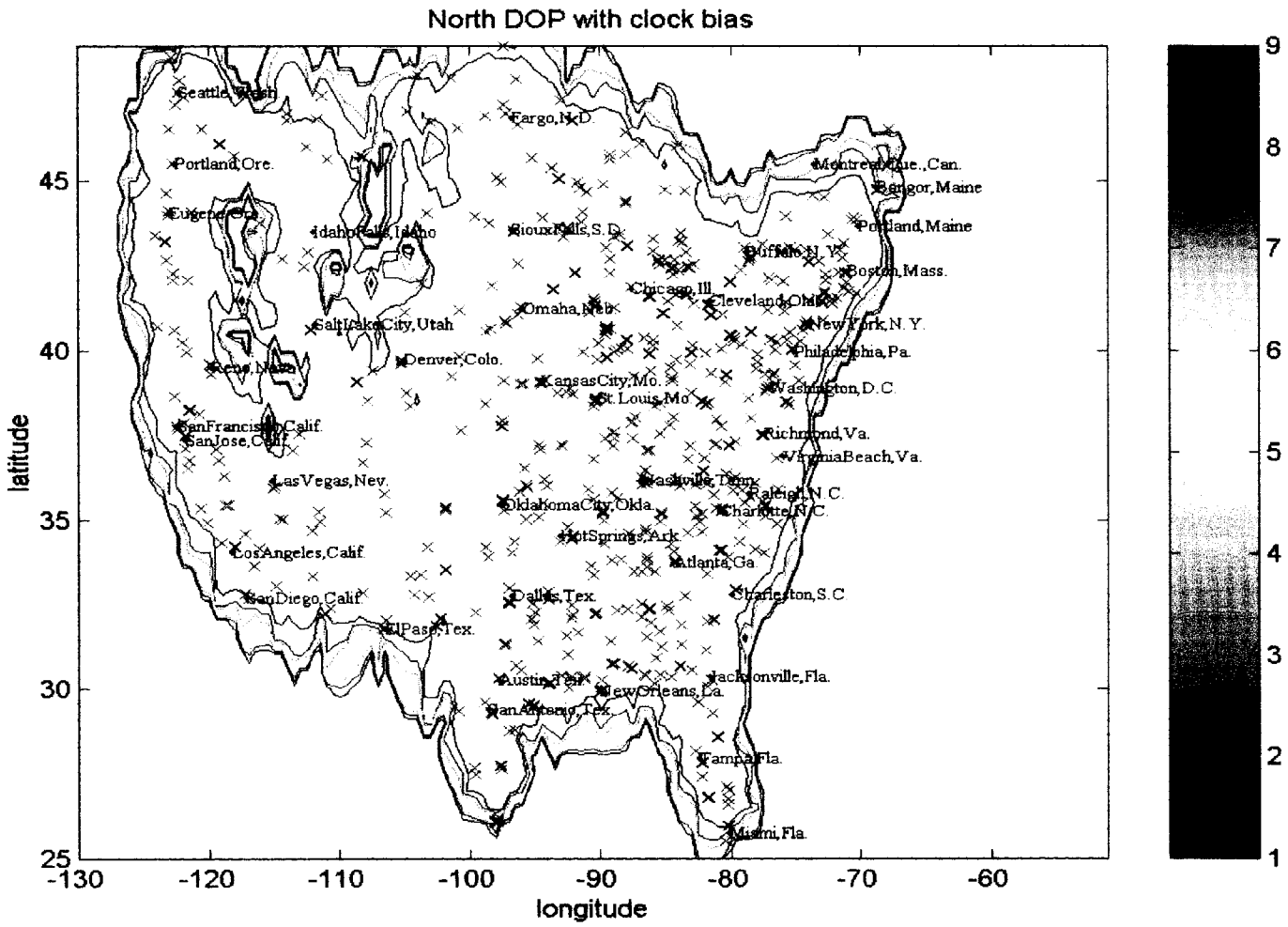
North DOP for 1038 Transmitters, UHF, No Channel Sharing



Example: Positioning in the Bay Area

- Areas without DTV positioning coverage are shown in red
- Analysis includes geographic features
- Generated by the same consultants that analyzed propagation for FCC

[redacted]

Revenue Sources: Strategy

- Phase One
  - E911 and Location-Based Service
    - Technology Licensing
    - Residual Licensing for Service
- Phase Two
  - Cell Phone Location (Europe & The World)
    - Technology Licensing
    - Residual Licensing for Service
  - Alternate Applications
    - PDA
    - Telematics (Automobiles)

[redacted]

Rosum Core Team

- Matthew Rabinowitz, Ph.D., CEO
- Jim Spilker, Ph.D., VP Eng and Chairman
- Matthew Pierce, Director of Business Dev.
- Jim Omura, Ph.D., CTO
- Paul Baran, Board Member
- James Gibbons Ph. D., Board Member
- Scott Chapman, Director of Application Software
- Roberto Collins, Director of Engineering
- Specialists in Antennas, Navigation, Digital Television, RF Design.

[redacted]

The Future: Strategic Overview

- Demonstration of the Technology
- Reference design for integration into a handset
- Equity participation by customers and partners
- Rollout for ubiquitous coverage of the USA
- Profitable revenues
- Rollout for coverage beyond the USA
- IPO or acquisition