Mobile Ku/Ka-band GEO Satellite Propagation Measurements using Automatic Tracking Dish Antenna for Emergency Telemedicine Services

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Abstract

This paper is addressed to report our evaluation study of GEO satellite-based Emergency Telemedicine services which installed in an ambulance car. From the measurement results, we concluded that the satellite is almost visible in Bandung, so the shadowing due to high building in Bandung is not degrading the transmission of vital biosignals from Ambulance to Hospital over Mobile Ku/Ka-band GEO Satellite Link.

1. INTRODUCTION

The provision of effective emergency telemedicine is the major field of interest discussed in this study. Ambulances is a common example of possible emergency sites, while critical care telemetry and telemedicine follow-ups are important issues of telemonitoring. The emergency telemedicine allows the transmission of vital biosignals such as *ECG monitor*, *Airway, Abdomen Echo,* and *Light Reflex* of the patient to Hospital by satellite links as illustrated in figure 1.

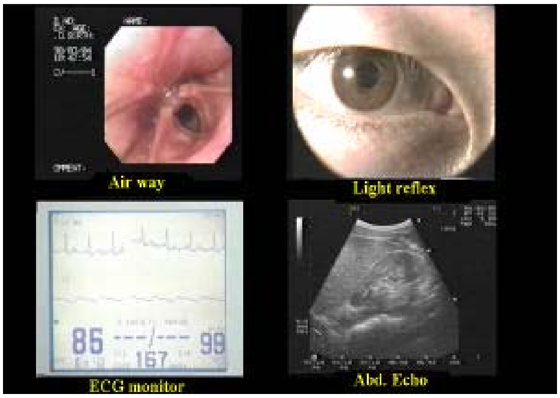

Figure 1. Vital biosignals (airway, light reflex, ECG monitor and Abdomen echo)

If the local triage center is able to access precise information about a patient being transported in an ambulance, more people can be saved by prehospital care and medical expenditures in Indonesia. If patients suffering from acute cardiac infarction receive appropriate treatment in an ambulance with the proper dose of thrombolytic under careful monitoring and blood pressure control, at least U.S.$2000 M in medical expenses could be saved in ten years.

Some case studies have suggested that data transmission via geostationary satellites offer great potential for emergency medical communications. Conversely, the shadowing (blocking) effects of many buildings and trees lining city streets will pose a problem for communication with satellites as shown in figure 2.

In this paper, we describes a newly-developed high-precision Ka-band GEO satellite tracking system for Emergency Telemedicine on the Ambulance as illustrated as in figure 3 below. The core of this tracking system comprises a quadrant detector for estimating the absolute coordinate of the satellite, while its relative coordinates are estimated by a GPS-based continuous kinematic positioning system.

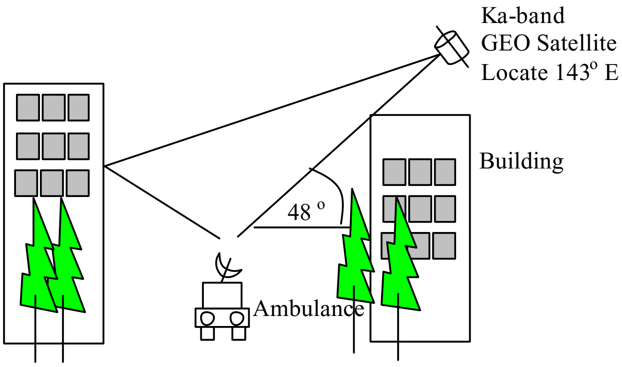

Figure 2.GEO-stationary-based Emergency Telemedicine

Figure 3. Automatic Tracking Dish for Super Ambulance Car

2. TARGET SATELITES

A geostationary satellite (GEO) may be used in areas near the equator and flat areas with few obstructions. Palapa C2 satellite is one of Indonesia satellites which has very high elevation angle (75-85 degree) and good Ku-band coverage over 60% of Indonesia archipelago as illustrated in figure 4 below.

On the other hand, right now under NiCT-Japan project on WINDS applications in Indonesia, we also have opportunity for using Gigatbit Ka-band Japanese Satellite, WINDS in Indonesia which has elevation angle 48 degree over West Java area as illustrated in figure 5 below. These two satellite are our target satellite for GEO-stationary based Emergency Telemedicine.

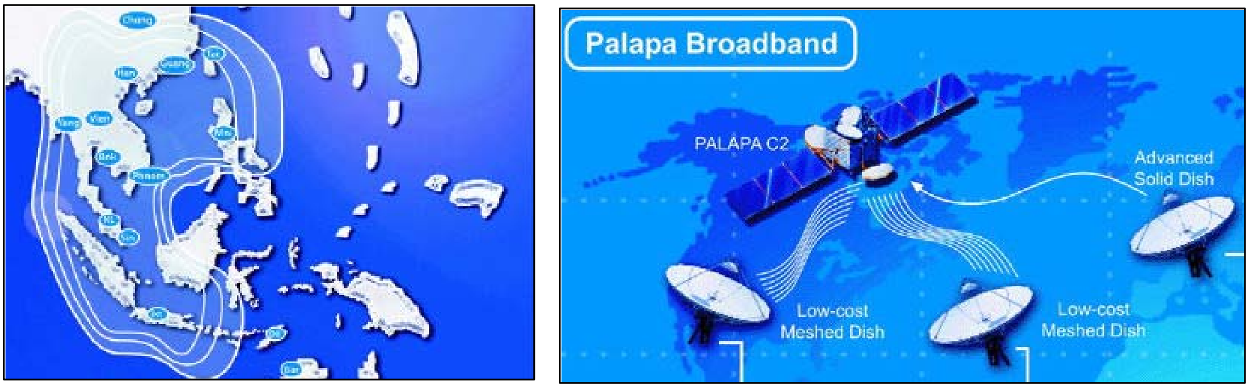

Figure 4. Palapa C2 Coverage and Ku-band Palapa C2 satellite model (Domestic Satellite)

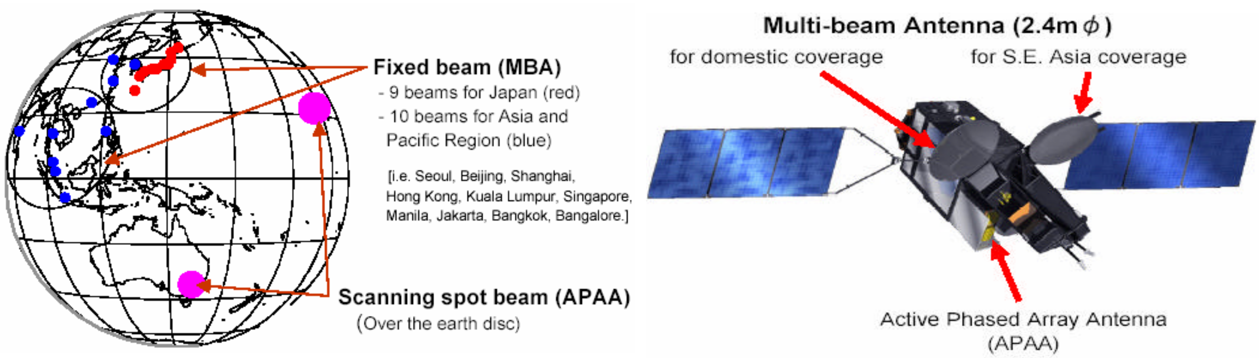

Figure 5. WINDS Coverage and Ka-band WINDS satellite model (Japanese Satellite)

3. SYSTEM DESIGN

A. Tracking Mechanics

We have mounted on the roof of an ambulance two tracking systems that can operate in the 25- 90 degree angle of elevation range and up to a continuous 660-degree azimuth range to track a Ku/Ka-band geostationary satellite. The drive system features a compact, simple design, and mechanically controls a Cassegrain antenna 50 cm in diameter (weight: kg; target radio bands: Ku and Ka; feeder unit: optional).

Two DC motor systems for azimuth and elevation control are installed, and the reduction gears have a harmonic drive mechanism with non-backlash gears aligned on a single input/output line. A transmission belt links the harmonic drive and turntable.

First, six parameters of the satellite's orbit are entered into an on-board computer, then the position gap detected by sensors is diminished step by step. Specifically, the on-board computer (running Linux) calculates the displacement of estimated satellite position from the true position based on data provided by input systems consisting of GPS sensors, fiber-optic 3D gyros, an inclinometer, and a quadrant detector.

Then, the computer generates an output signal to control the drive motors (of the azimuth and elevation control systems). The step-tracking method (with 3-5 operations per second) has a closed loop of sensors and motors. It first corrects 50% of the total positioning error, then performs fine-tuning based on feedback from the sensors. The following A-D sensors provide the tracking system with information about azimuth (AZ) and elevation (EL) control. The indoor unit of Automatic tracking dish antenna is shown as figure 6 below :

Figure 6.The indoor unit of Automatic tracking dish antenna

B. GPS interference positioning

GPS interference positioning and continuous kinematic positioning are technologies used to receive signals simultaneously sent from GPS satellites at two sites, and to determine the relative coordinates of one receiving point against the other based on the measured phase of the carrier wave. We obtain directional data in 3D coordinates from three GPS receivers.

The GPS interference positioning provides higher accuracy than the popular single positioning method or socalled translocation method. Such positioning can obtain relative coordinates approximating the absolute coordinates of the target satellite (particularly in the X-Y plane).

C. Quadrant Detector

Data transmission from an ambulance to the satellite is the major part of data flow in the current system. However, concarrently with transmission four spatially separated receiving circuits (all located the same distance from the center of the Cassegrain antenna feeding unit) concurrently catch weak pilot beacons sent from the satellite.

Four DSPs along the time axis integrate these received signals to calculate four magnitudes of electric power. The differences between these four values of arriving power are determined based on the beacon angle and four spatial coordinates. The output given to the drive system for fine-tuning of the azimuth and angles of elevation can then be calculated with reference to a conversion table covering each antenna pattern. For use under multipath conditions (e.g., with Nakagami-Rice fading, Loo distributionj), the quadrant detector works better than so-called monopulse antennas because it has an independent array structure (i.e., independent heterodyne receiver).

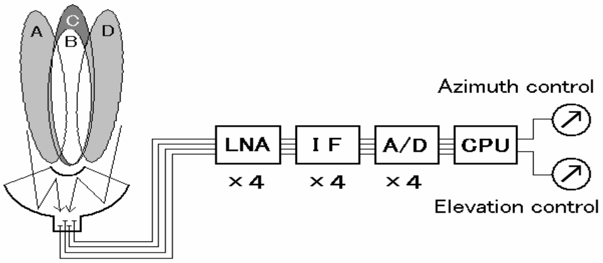

Figure 7. Block diagram of Quadrant Detector

The monopulse antenna is widely used in a number of radar tracking systems to indicate the direction of arriving signals by a simple comparison of voltage amplitudes, and by integrating the voltage values of the same phase with those of the reverse phase. The quadrant detector provides the absolute coordinates of the satellite.

D. Accelerometer and Inclinometer

We used commercially available accelerometers and inclinometers to determine the conditions of emergency ambulances in operation.

4. TRACKING PROTOCOL

A. Initial acquisition

The first method used to locate a satellite. The satellite's six elements, time, present location (GPS data), and antenna elevation are easily calculated. Optimal positions are sequentially calculated according to bearings (using a laser-gyro at present).

B. Tracking

Comparing and controlling signal strength from a satellite using QD.

C. Re-acquistion

When a vehicle changes direction at a traffic intersection or brakes or accelerates, it frequently needs to reacquire the signal, since inertia tends to force the antenna into a position precisely opposite an optimal position.

D. Distinguishing a traffic intersection from shadowing

A traffic intersection can be distinguished from shadowing using GPS data.

TABLE I. TRACKING PROTOCOL

	QD	GPS	FOG	MSW	SOE
Initial acquisition	④	①	③		②
Tracking	①	②			
Re-acquisition		①	②		
Shadowing or Turning	④	③	①	②	

QD:Quadrant Detector
GPS:Global Positioning System
FOG:Fiber Opical Gyro
MSW:Mappping Soft Ware
SOE:Six Orbital Elements

5. PROPAGATION MEASUREMENT RESULTS

For evaluating the transmission quality due to the shadowing, we have performed the satellite visibility measurements at Bandung (as illustrated in figure 8), Indonesia with Ka -band GEO Satellite located at 143^{o} E as the target satellite.

From the measurement results as illustrated in Table II, we concluded that the satellite is almost visible in Bandung, so the shadowing due to high building in Bandung is not degrading the transmission of vital biosignals from Ambulance to Hospital.

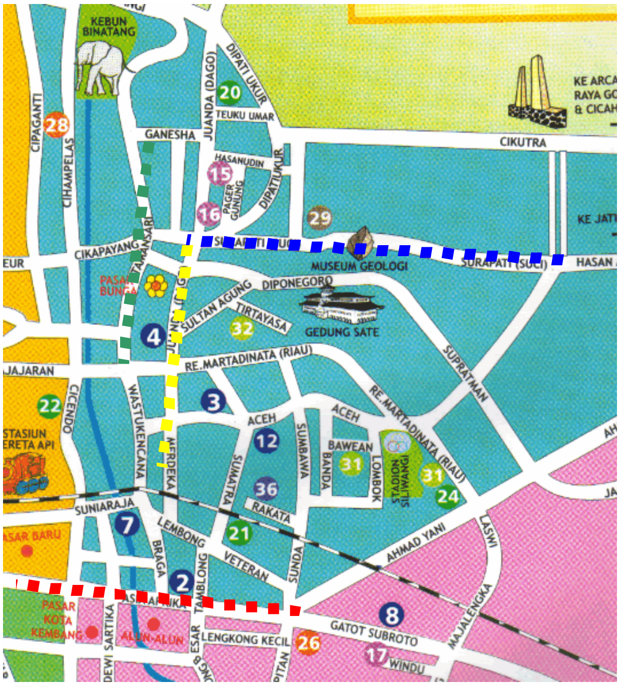

Figure 8 Bandung Map : Dago, Suci, Asia Afrika and Cihampelas Road

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TABLE II. VISIBILITY OF KA-BAND GEO SATELLITE O VER BANDUNG

Road	Building	Width	Orientation	Road	Visibility	Ricean	Rayleigh	Link Av
Dago	2 - 3 Floor	3 lane	South-North	Dago	80 %	$P_{rice} = 0.8$	$P_{ray} = 0.2$	96%
Suci	2 - 3 Floor	3 - 4 lane	East-West	Suci	90%	$P_{rice} = 0.9$	$P_{ray} = 0.1$	99%
Asia Afrika	3 - 5 Floor	2 -3 lane	East-West	Asia Afrika	70%	$P_{rice} = 0.7$	$P_{ray} = 0.3$	95%
Cihampelas	2 - 3 Floor	2 lane	South-North	Cihampelas	70%	$P_{rice} = 0.65$	$P_{ray} = 0.35$	93%