Computer Simulation of Compensated Dish Antenna Positioning System Mounted On Distributed Telemedicine Mobile Network

DR. OKOLIE S.A.[1], NWABUEZE E.C.[2], OKORONKWO C.[3], AKPAN E.I.[4]
[1,2,3,4] *Department of Computer Science, Federal University of Technology, Owerri, Nigeria*

***Abstract-* In mobile networks, effective communication among distributed nodes is a perquisite to achieving adequate data/information sharing, signal transmission and reception, fast response and stability. With the aid of computer simulation software such as MATLAB, the performance of a communication system can be studied. In this paper, a computer simulation has been conducted to study the performance characteristics of dish antenna system mounted on distributed telemedicine mobile network. A compensation algorithm was designed and added into the network loop, which was represented by transfer function. Simulation results indicated that the addition of the compensation algorithm largely enhance the overall time domain response performance of the system in terms of rise time (2.75 s), peak time (6.73 s), overshoot (4.87%), settling time (10.1s) and steady state error (0 at 30 s).**

***Indexed Terms-* Compensator, Computer simulation, Mobile network, Telemedicine.**

I. INTRODUCTION

The increasing improvement in wireless communications and networking technologies, coupled with advances in computing and medical technologies, facilitate the development and offering of promising mobile systems and services in the healthcare sector. The emergence of information communication technology (ICT) has played essential role in making healthcare delivery more affordable and available with far reaching effect for both rural and urban populations. Thus, the severe shortage of medical workers and the low level of healthcare delivery existing in developing countries such as Nigeria can be reduced by proper implementation of ICT. Telemedicine is a combination of wired and wireless transmission of medical information where biological signals, images and videos are conveyed to remote location for diagnosis. This reduces the demand on healthcare workers and compensates the physical distance between patients and caretakers [1]. Telemedicine offers the sophisticated health care system via electronic communication that makes patient health care better. The application of mobile communication in sending medical information brings about a new term called m-health, which can be described as mobile computing, medical sensor, and communications technologies for healthcare [1].

This paper is concerned with designing a computer simulated compensation algorithm to improve tracking performance while improving the delay handling capacity of satellite dishes mounted on mobile telemedicine vehicles. The arrangement is a mobile network communicating within Nigeria at a maximum speed of 240 km/hr to point and lock onto NigComSat-1R quickly and precisely [2]. The mobile network for communicating telemedicine nodes considered in this paper is subject to two major sources of time delay which are the position within Nigeria of a telemedicine vehicle with a satellite dish mounted on it; and the vehicle moving at a speed of up to 240 km/hr [3].

In telemedicine network configuration, two most stringent requirements to be met are space and time [1] [4]. The time requirement of telemedicine comes with improved mobility and efficiency. With the Nigerian government successfully launching a geo-stationary communication satellite NigComSat-1R, with one of the pilot projects being telemedicine [5], it has been reported in literature by Ajiboye et al. [6] that this system being part of Networked Control Systems (NCSs) is prone to propagation delays. Hence, there is need to integrate an electronic digital compensator in the distributed network of telemedicine nodes. The remaining part of this paper will be organized as follows: section two will examine the existing system with respect to the time delay. Section three is the methodology, wherein the study establishes the mathematical model representing the dynamics of the system, develop a computational algorithm of the compensator using MATLAB software and then provide the MATLAB programme for implementation. Section four is the discussion of the results obtained from the simulations conducted in MATLAB simulation environment. Section five presents the conclusion.

II. DETERMINATION OF PROPAGATION TIME DELAY RANGE

The time delay arising due to propagation effect can be large in view of the fact that Nigeria has a vast land area of 923,677 sq km and extensive geographical coordinates between longitude 2°43.207'E and 14°54.685'E and latitude 4°17.825'N and 13°52.837'N [2]. The detail modeling and experiment carried out for determining the propagation time delay of the considered mobile network with dish antenna mounted telemedicine nodes capacity can be found in [2][6].

Fig.1 shows with the letter A, B, C and D, the location and geographical coordinates of various points. Description of points: (a) point A is located at Niger Republic and at coordinate 2°43. 207'E, 13°52.837'N (b) point B is located at Lake Chad and at coordinate 14°54. 685'E, 13°52.837'N (c) point C is located at Gulf of Guinea and at coordinate 2°43. 207'E, 14°17.837'N; point D is located at Cameroon and at coordinate 14°54.685'E, 4°17.825'N. The sub-satellite point for NIGCOMSAT-1R satellite is at 42.5°E, 0° [7].

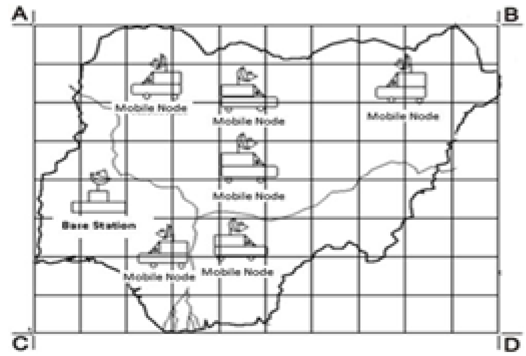

Fig. 1 Geographical map of Nigeria showing distribution of telemedicine nodes [2] [7]

Parameters necessary for determining time delay are the distance between the base station and mobile telemedicine nodes and signal speed. The distance between any two points on the earth surface via geostationary satellite is given by Ibiyemi and Ajiboye[2], Ibiyemi and Ajiboye [3],; Ajiboye et al. [7], Ibiyemi and Ajiboye [8]:

$$d_{sr} = \sqrt{D^2 + R^2 - 2DR\cos(\alpha_{sn})\cos(\Delta_{sn} - \Delta_s)} + \sqrt{D^2 + R^2 - 2DR\cos(\alpha_{rn})\cos(\Delta_{rn} - \Delta_s)}$$

(1)

where, d_r = is the distance between source and the receiving node,

R = radius of the earth in km,

D = sum of the radius of the earth and satellite altitude in km,

Δ_s = angle of longitude of the sub-satellite point in degrees,

α_{sn} = latitude of the sending node location on the earth surface in degrees,

α_{rn} = latitude of the receiving node location on the earth surface in degrees,

Δ_{sn} = angle of longitude of the sending node location on the earth surface in degrees, and

Δ_{rn} = angle of longitude of the receiving node location on the earth surface in degrees.

The time delay arising from sending signal between the sending node and the receiving node was obtained by dividing the distance by the signal speed and is given by:

$$T = \frac{d_{sr}}{v} \quad (2)$$

where: T is the time delay in seconds and v is the signal speed in m/s.

III. METHODOLOGY

A. System Modelling

The system is represented by transfer function which was determined considering the dish and jack actuator dynamics model. "The determination of the dynamic was based on the moment of inertia of the dish structure (satellite dish and BUC/LNB), spring constant, and damping coefficient. These parameters were determined by experiment because their value cannot be read off the plant at the node" [7] [8].

The transfer function of the mobile network with mounted dish antenna system is given by [3] [7]

$$G_p(s) = \frac{3.76}{s^4 + 67.56s^3 + 62.36s^2 + 150.52s} \quad (3)$$

The transfer functions of the time delay for forward and feedback paths are given by [7]:

$$\left.\begin{aligned} G_{d1}(s) &= e^{-T_1 s} \\ G_{d2}(s) &= e^{-T_2 s} \end{aligned}\right\} \quad (4)$$

where:

T_1 = Feed forward delay from base station to the node in seconds and

T_2 = Feedback delay from the node to base station in seconds.

Now, assuming that the feed forward time delay is equal to feedback time delay, such that $T_1 = T_2 = T$. Equation (4) can be expressed as:

$$G_{d1} = G_{d2} = G_d = e^{-Ts} \quad (5)$$

The maximum and minimum time delay was determined to be 0.2502s and 0.2469s [7].

B. Compensator Design

The essence of the compensator computation algorithm is to compensate for the time delay and improve the positioning error of the dish antenna in the network node for efficient tracking performance. The compensation algorithm whose mathematical computational model was developed using MATLAB software based on optimization based tuning (OBT) design method is given by:

$$C(s) = 13 \times \frac{s(0.25s+1)}{s(1+s)} \quad (6)$$

C. Implementation Programme

The computer computational algorithms for implementing the performance of dish antenna positioning system in a distributed mobile telemedicine network for uncompensated condition and compensated condition are given in Fig. 2 and 3 respectively.

```
clc;
clear;
closeall;

% Determine the close loop transfer function of the system
num = 3.76;  % system numerator
den = [1 67.56 62.36 150.52 0]; % system denominator
 s = tf('s'); % expression for s-domain function
 Gp = tf(num,den); % dish antenna system transfer function
 Gd = exp(-0.25*s); % delay function in laplace transform
 G = Gp*Gd; % obtain the product of dish antenna system
transfer function and delay function

% Determine step response of uncompensated system
sys_cl =feedback(G,Gd); % closed loop with feedback delay
function
 [y,t] = step(sys_cl,350);
stairs(t,y)
xlabel('Time (s)')
ylabel('Position (degree)')
title('step Response: original')
```

Fig. 2 MATLAB programme for uncompensated system

```
clc;
clear;
close all;
% Determine the close loop transfer function of the
system
num=3.76;% system numerator
den = [1 67.56 62.36 150.52 0]; % system denominator
 s = tf('s'); % expression for s-domain function
 Gp = tf(num,den); % dish antenna system transfer
function
 Gd = exp(-0.25*s); % delay function in Laplace
transform
 G = Gp*Gd; % obtain the product of dish antenna
system transfer function and delay function

 % Determine the compensator in continuous time
domain
 a =[3.25 13 0]; % compensator numerator
 b = [1 1 0]; % compensator denominator
 C = tf(a,b); % design compensator

  % Determine the compensated close loop
  sys_cl1 = feedback(G*C,Gd) ;% closed loop with
compensator and feedback delay function
 [y,t] = step(sys_cl1,45);
stairs(t,y)
xlabel('Time (s)'),
ylabel('Position (degree)')
title('step Response: with compensator')
```

Fig. 3 MATLAB programme for compensated system

IV. SIMULATION RESULT S AND DISCUSION

This section presents the results of the simulation carried out in MATLAB. These results are shown for two separate conditions considered in this paper. That is the conditions when no compensation algorithm has been introduced into the dish antenna positioning system and when a compensation algorithm has been into the mobile network of the distributed telemedicine node. Fig. 4 is the simulation result in terms of step response for the uncompensated system using the programme in Fig. 2, while the step response result obtained using MATLAB code in Fig. 3 for the compensated system is shown in Fig. 5. Table 1 shows the time domain parameters of the system response performance analysis to step input.

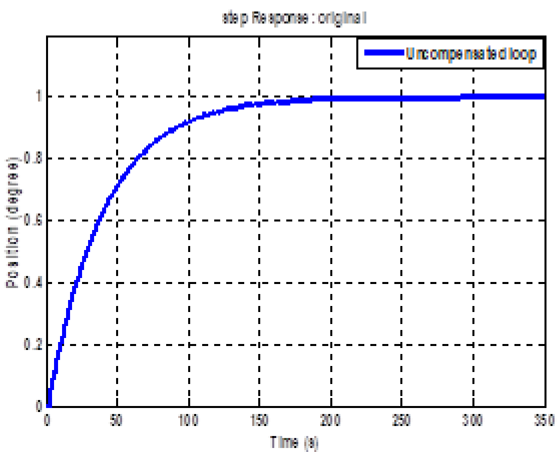

Fig. 4 Step response performance for uncompensated system

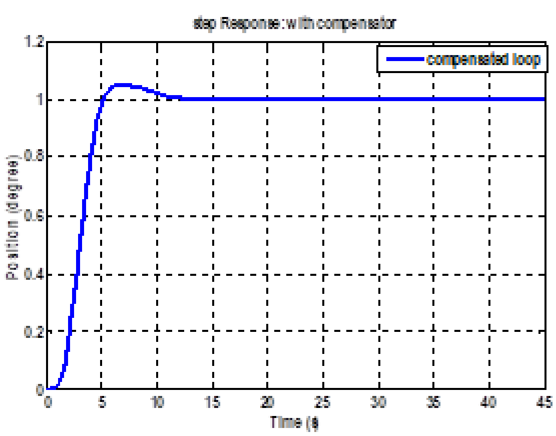

Fig. 5 Step response performance for compensated system

Table 1 Step response time domain performance analysis

System condition	Rise time	Peak time	Overshoot	Settling time	Steady state error
Uncompensated system	86 s	300 s	0%	154 s	0 at 350 s
Compensated system	2.75 s	6.73 s	4.87 %	10.1 s	0 at 30 s

V. CONCLUSION

This paper has implemented an algorithm to compensate for time delay effect in distributed telemedicine mobile network. Mathematical equations representing the dynamics of antenna system and time delay were obtained. The system has been fully designed and analysed using MATLAB Software. Results from the simulations showed that the compensator effectively compensates for the time delay and improved general characteristics of dish antenna response within the network.

APPENDIX

The MATLAB Graphical User Interface (GUI) for the compensator design.

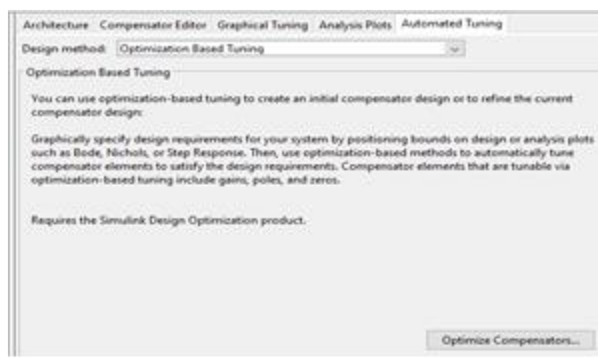

Fig. A1 Optimization based tunning GUI

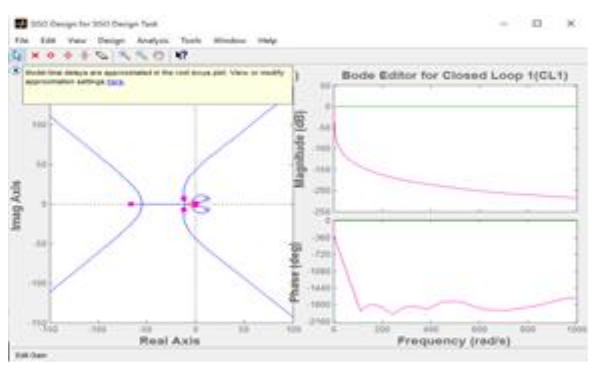

Fig. A2 Single Input Single Output (SISO) design task

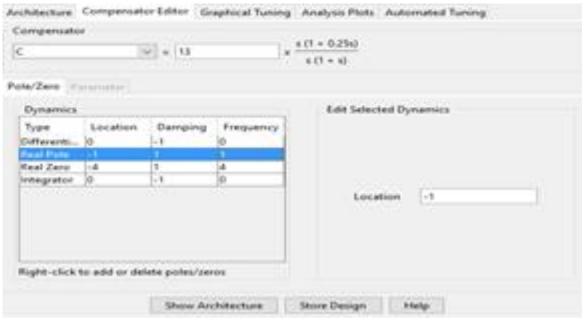

Fig. A3 GUI of the designed compensator

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