Answer 1

First generation mobile communication

The first generation of mobile communication was based on analog system. It was introduced in 1980 for the first time. Advanced mobile phone system (AMPS) was the first most popular analog systems and was launched in the United states of America. All of the standards in 1G use frequency modulation techniques for voice signals. The spectrum within cell was divided into number of channels which was not efficient in terms of the available radio spectrum, and this placed a limitation on the number of calls that could be made at any one time. Analog systems were based on circuit switching technology and offers only voice communication and no data communication. (Jyotsna Agrawal, 2015)

Main features and strengths of 1G

- It is based on analog system
- Supports data speed of up to 2.4 kbps
- (Jyotsna Agrawal, 2015)Example: cordless telephone

Weaknesses of 1G

- supports only voice and no data communication
- Low capacity
- Poor handoff mechanism
- Poor security
- Poor quality voice link

Second generation mobile communication

2G was an improvement over 1G and was introduced in late 1980s. It was based on low band data signaling. Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) replaced the analog technology. GSM (Global systems for mobile communications) is the most popular 2G wireless communication system. It can support multiple users. The TDMA breaks down data transmission, such as a phone conversation, into fragments and transmits each fragment in a short burst, assigning each fragment a time slot. With a cell phone, the caller does not detect this fragmentation. During development over more than 20 years, GSM technology has been continuously improved to offer better services to its users. GSM supports 450 million cellular subscribers, with international roaming in approximately 140 countries and 400 networks. CDMA uses spread spectrum technology to break up speech into small, digitized segments and encodes them to identify each call. The CDMA distinguishes between multiple transmissions carried simultaneously on a single wireless signal. It carries the transmissions on that signal, freeing network room for the wireless carrier and providing interference-free calls for the user. The CDMA breaks down calls on a signal by codes, whereas TDMA breaks them down by time. The result in both cases is an increased network capacity for the wireless carrier and a lack of interference for the caller.

Main features and strengths of 2G

- Better spectrum efficiency
- Provides data rate up to 64 kbps
- Improved system capacity and network coverage
- Roaming facility
- Voice and data services both available
- Improved security

Weaknesses of 2G

- Does not support high data rates
- Weak digital signal
- Unable to handle complex data

Third generation mobile communication

3G was one of the biggest change in the world of wireless communication. The 3G fulfils the specifications of International Mobile Telecommunications-2000 (IMT2000), the official International Telecommunication Union which intended to provide wireless access to global telecommunication system. To meet the IMT-2000 standards, a system is required to provide peak data rates of at least 200 Kbit/s. The most important IMT-2000 proposals are the Universal Mobile Telecommunications System (UMTS) as the successor to GSM. The UMTS uses the W-CDMA, TD-CDMA, or TD-SCDMA air interfaces in which WCDMA is the most popular air-interface technology for the UMTS. The main components include BS (Base Station) or nod B, RNC (Radio Network Controller), apart from WMSC (Wideband CDMA Mobile Switching Centre) and SGSN/GGSN. The W-CDMA gives additional advantages of high transfer rate, and increased system capacity and communication quality by statistical multiplexing. The WCDMA utilizes efficiently the radio spectrum, because the CDMA technique enables all base stations to use the same frequency. In the WCDMA system, the data is split into separate packets, which are then transmitted using packet switching technology, and the packets are reassembled in the correct sequence at the receiver end by using the code that is sent with each packet. The UMTS systems are designed to provide a range of data rates, depending on the user's circumstances, providing up to 144 kbps for moving vehicles, up to 384 kbps for pedestrians and up to 2 Mbps for indoor or stationary users. The3G basically focused on multimedia applications such as video calling, videoconferencing for mobile phones, improved capacity, world roaming, low cost, better compatibility, high speed data.

Main Features and strengths of 3G

- Faster data rates
- Supports multimedia applications like video and photography

- Value added services like mobile television, GPS, Video call and conferencing
- High speed mobile internet access
- Internet capacity

Weaknesses of 3G

- Requires 3G compatible handsets
- The cost of upgrading to 3G devices is expensive
- Power consumption is high
- 3G requires closer base stations which is expensive

Fourth generation mobile communication

In order to cater the higher data requirements, efforts were made to improve the downlink and uplink throughput rates by applying higher modulation techniques. Long Term Evolution Project(LTE) was launched by 3GPP to ensure the continuous competitiveness of the UMTS in the future. As LTE is considered as the evolution of universal mobile telephone system (UMTS), hence LTE's equivalent components are thus named evolved UMTS terrestrial radio access (EUTRA) and evolved UMTS terrestrial radio access network (EUTRAN). The basic architecture of LTE contains a separate IP connectivity layer for all the IP based services and Evolved Packet System (EPS) which handles the overall communication procedure. LTE is IP based system. LTE is very flexible when it comes to connectivity. An operator with a GPRS/EDGE network or aNon3GPP systems can connect to a LTE network. Due to this increased flexibility, LTE is the choice of majority of operators worldwide. By using Orthogonal Frequency Division Multiple Access (OFDMA), LTE will be able to provide download rates of about 100 Mbps for multi-antenna (2x2), multiple-input multiple output (MIMO) for the highest category terminals. For these terminals upload rate is about 50 Mbps. Moreover, it provides better mobility, efficient radio usage, high level of security, flexible spectrum utilization, reduced delay/latency, cost efficient deployment and various other advantages which makes LTE more reliable and user friendly.

Main Features and strengths of 4G

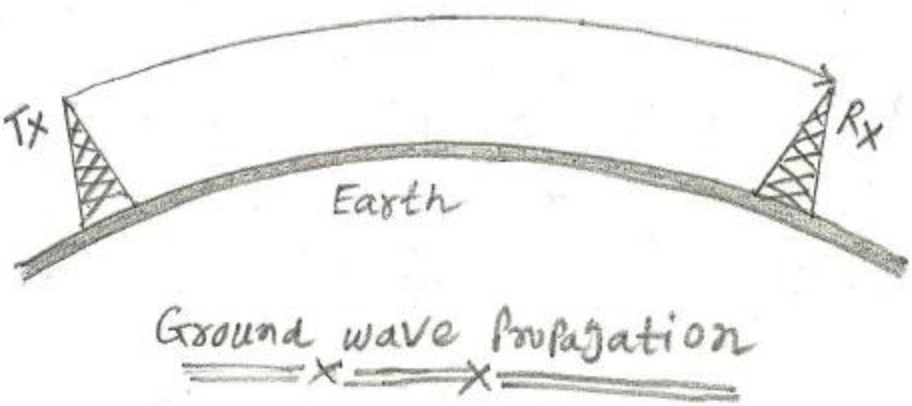
- High Spectral efficiency
- High voice quality
- Easy access to internet and streaming video
- Low latency
- Simple architecture
- Efficient multicast/broadcast

Weaknesses of 4G

- Higher data prices for the consumers
- Very expensive and hard to implement
- Complex hardware
- More power usage

Answer 2

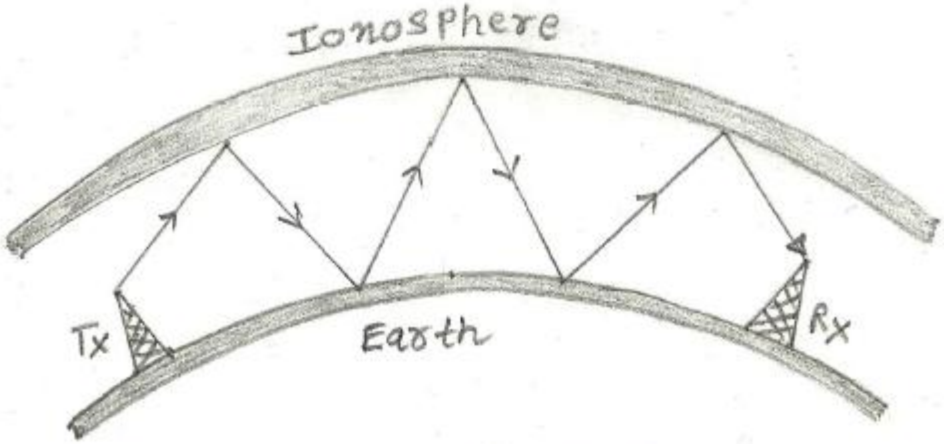
Ground wave propagation:



Ground wave propagation operates below 2 MHz frequency. It covers ELF, SLF, ULF, VLF, LF, and MF frequency bands. This kind of signal exists very close to surface of the earth. It follows earth's contour and hence can propagate to considerable distances. At lower frequencies, interference occurs due to atmospheric noise only. The power of transmission here is sufficient and hence maximum range of about 5000 miles can be achieved. Optimum antenna size is about λ/2. As the distance from transmitter increases received signal strength decreases and follows exponential curve. (http://www.rfwireless-world.com/Terminology/sky-wave-vs-LOS-wave-vs-ground-wave.html)

They are also known as surface waves. They are used up to maximum frequency range.
Example: AM radio

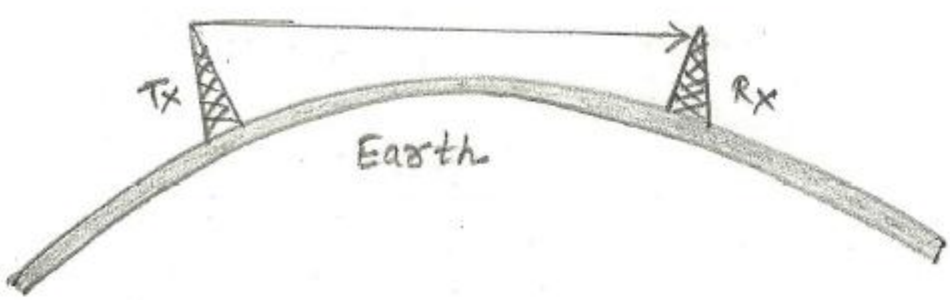
Sky wave propagation:



Sky wave Propagation

Sky wave operates between 2 MHz to 30 MHz range of frequency and covers ELF, SLF, ULF, VLF, LF, MF, and HF frequency bands. It exists in the sky and is dependent upon reflective characteristics of ionosphere layer. The signal is reflected from ionized layer of the atmosphere. In this propagation mode, signals can travel number of hops, back and forth. The example of this type is SW (Shortwave) radio. Sky wave travels larger distances during night time since ionosphere is closer to earth's surface during night. It travels at a flatter angle. There are more skip zones which results into no reception. During the daytime, ionosphere layer is away from the earth surface. It travels with an angle. It travels smaller distances. There are less skip zones with no reception.

Line of sight propagation



Line-of-Sight Propagation

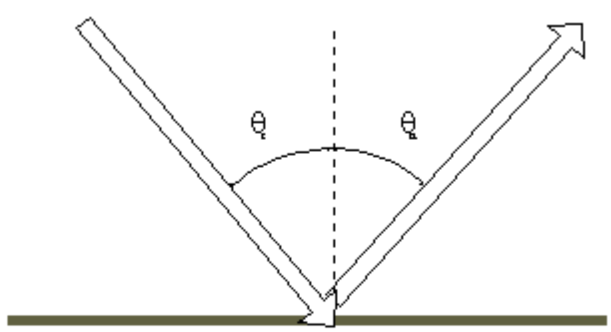
Line of sight propagation exist from above 30 MHz and covers VHF, UHF, SHF, and EHF frequency bands. LOS wave travels in straight line. propagation follows laws of free space. Both transmitting antenna and receiving antenna must be within LOS (Line of Sight). Examples are satellite communication and ground communication.
In the VHF band, LOS signal will be affected by reflection of various objects on the earth.

Non-Line of sight propagation

Non-line of sight is a term often used when the radio transmitter and receiver are not in the direct visual line of sight, and this is dealt with by the use of multiple paths in signal propagation. Non-line of sight can be overcome with the use of antennas and other such communication devices. Distance also plays a significant role in lowering the receiving power of a signal, leaving a poor transmission system. Modern computer networking's biggest concern is to effectively reduce the NLOS, and this is done on wireless networks by using relays at various points so that the signal is transmitted around the obstruction without loss of data or transmission quality. Multipath signal propagation is also widely used.
(https://www.techopedia.com/definition/5077/non-line-of-sight-nlos)

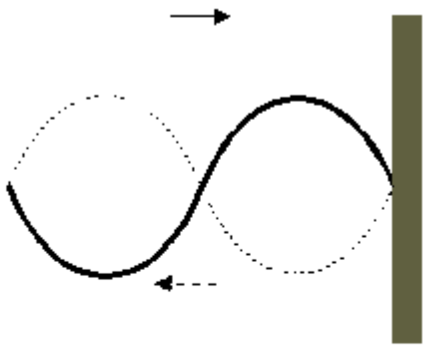
Answer 3

Reflection



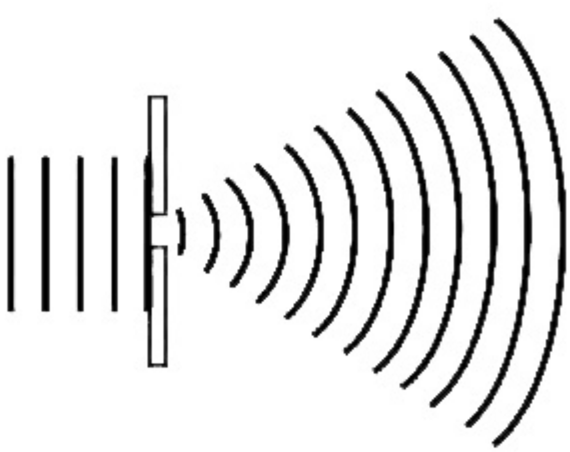
When a plane wave encounters a change in medium, some or all of it may propagate into the new medium or be reflected from it. The part that enters the new medium is called the transmitted portion and the other the reflected portion. The part which is reflected has a very simple rule governing its behavior.
Angle of Incidence = the angle between the direction of propagation and a line perpendicular to the boundary, on the same side of the surface. Angle of Reflection = the angle between the direction of propagation of the reflected wave and a line perpendicular to the boundary, also on the same side of the surface. Then the rule for reflection is simply stated as:

The angle of reflection = The angle of incidence



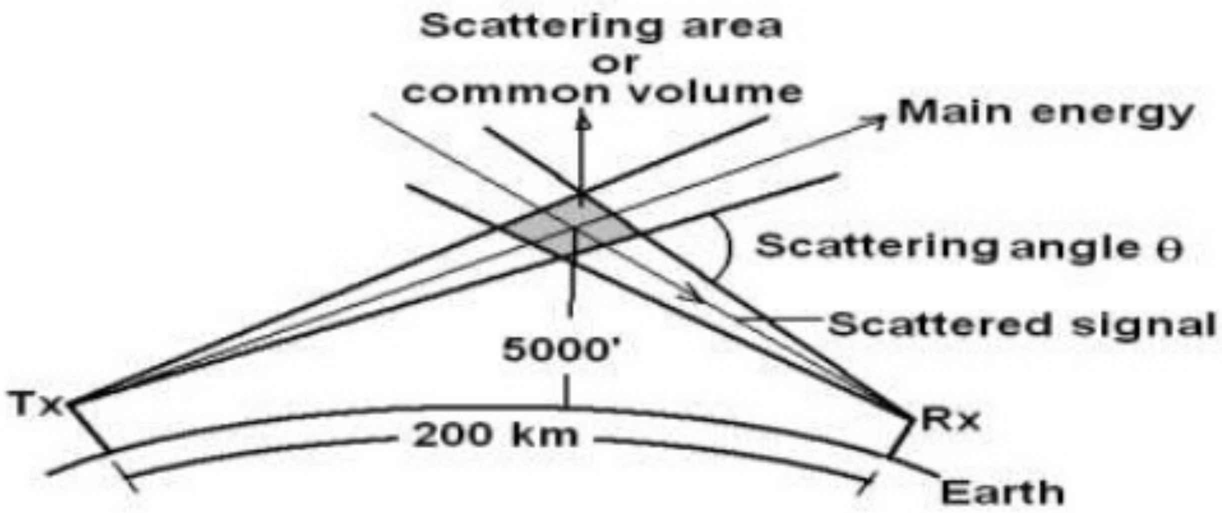
If the incident medium has a lower index of refraction, then the reflected wave has a 180^0 phase shift upon reflection. Conversely, if the incident medium has a larger index of refraction the reflected wave has no phase shift

Diffraction



We observe the phenomenon of waves bending around corners every day, e.g. when we hear sound from sources that are out of sight around a corner. Light can also bend around corners. When light from a point source falls on a straight edge and casts a shadow, the edge of the shadow is not a perfectly sharp step edge. Neither is the shadow of the edge just smeared out. There is some light in the area that we expected to be in the shadow, and we find alternating bright and dark fringes in the illuminated area close to the edge. This is the result of interference between many light waves (Huygens' Principle). Such effects are referred to as diffraction.

Scattering



Scattering is a physical process that causes radiation to deviate from a straight trajectory. We saw this in the introductory sections on reflection: If there were microscopic irregularities in the surface we would get diffuse instead of specular reflection. The same goes for radiation passing through a transparent medium: If there are non-uniformities like particles, bubbles, droplets, density fluctuations etc., some of the radiation will deviate from its original trajectory. In a physical description of the phenomenon, we distinguish between two types of scattering, namely elastic and inelastic. Elastic scattering involves no (or a very small) loss or gain of energy by the radiation, whereas inelastic scattering does involve some change in the energy of the radiation. If the radiation is substantially or completely extinguished by the interaction (losing a significant proportion of its energy), the process is known as absorption. When radiation is only scattered by one localized scattering center, this is called single scattering. Single scattering can usually be treated as a random phenomenon, often described by some probability distribution. (Albregtsen)

Answer 4

Coherence Bandwidth
is a statistical measurement of the range of frequencies over which the channel can be considered "flat", or in other words the approximate maximum bandwidth or frequency interval over which two frequencies of a signal are likely to experience comparable or correlated amplitude fading.

It can be reasonably assumed that the channel is flat if the coherence bandwidth is greater than the data signal bandwidth. The coherence bandwidth varies
over cellular or PCS communications paths because the multipath spread *D* varies from path to path.
(Wikipedia)
We can determine the value of Coherence bandwidth by following formula with depends on RMS delay spread.

Coherence Bandwidth ≈ 1/ (2 π * RMS Delay Spread)

Frequencies within a coherence bandwidth of one another tend to all fade in a similar or correlated fashion. One reason for designing the CDMA IS-95 waveform with a bandwidth of approximately 1.25 MHz is because in many urban signaling environments the coherence bandwidth B_c is significantly less than 1.25 MHz. Therefore, when fading occurs it occurs only over a relatively small fraction of the total CDMA signal bandwidth. The portion of the signal bandwidth over which fading does not occur typically contains enough signal power to sustain reliable communications. This is the bandwidth over which the channel transfer function remains virtually constant.

If the delay spread *D* over a particular cellular communication path in an urban environment is 1.9 μs, then using equation above, the coherence bandwidth is approximately 0.53 MHz, which results in frequency selective fading over the IS-95 bandwidth.

Coherence Time

is the time duration over which the channel impulse response is considered to be not varying. In other words, coherence time is the time duration over which two received signals have a strong potential for amplitude correlation. If the reciprocal bandwidth of the baseband signal is greater than the coherence time of the channel, then the channel will change during the transmission of the baseband message, thus causing distortion at the receiver. Such channel variation is much more significant in wireless communications systems, due to Doppler effects.

Distortion occurs if the period of the baseband signal is greater than the coherence time. This happens because the channel will change during the transmission of the signal and will be variant as duration of the symbol period is more than the coherence time.

We can determine the value of Coherence time by following formula:

Coherence time = 1/ (2 π * Fmax)

Where, F max = vehicle speed/λ

λ = c/ RF carrier Frequency

We can classify the multipath time delay spreading into two parts:

1. Frequency flat fading
2. Frequency slow fading

Frequency flat fading

Frequency flat fading occurs when Bs which denotes the bandwidth of the signal is much smaller than B_c - the coherence bandwidth. This implies that sigma tau which is the RMS delay spread is much less than Ts - the symbol duration. Now sigma tau is only a function of the environment. It has nothing to do with the signal. So if in a small room environment with lot of reflectors, if sigma tau is much smaller than tau S, then in that case we will experience something called as a 'frequency flat fading'. In these scenarios, we typically find that the received amplitude to be statistically distributed either as a Rayleigh or Ricean. The spectral characteristics of the transmitted signal is preserved in the case of flat fading

Frequency selective fading

Frequency selective fading occurs when the bandwidth of the signal is greater than the Coherence bandwidth i.e. B_c

it equally implies that sigma tau should be greater than Ts the symbol duration. in this case intersymbol interference occurs. The other feature of a frequency selective channel is that the spectral characteristics of the transmitted signal is not preserved. This is the major impediment but it can be also viewed from the other side of the coin which is, you can have uncorrelated fading for one part of the signal with respective the other part of the bandwidth.

Answer 5

a. 90% coherence bandwidth B_c = 1 / 50σ = 1/ (50 x 4us) = 5 kHz
b. Max Doppler shif can be calculated using the below formula:

   $D = f_c v / c$

   Where f_c = carrier frequency

   v = velocity of vehicle

   v in m/s = 250 x 0.28 = 70

   D=(5×10e6× 70)/(3×10e8)= 1.17

c. 50% coherence bandwidth B_c = 1 / 5σ = 1/(5 x 4us) = 50 kHz
d. Since symbol duration (66.7us) >> rms delay spread i.e. σ (4us)
   ⇨ This is frequency flat fading

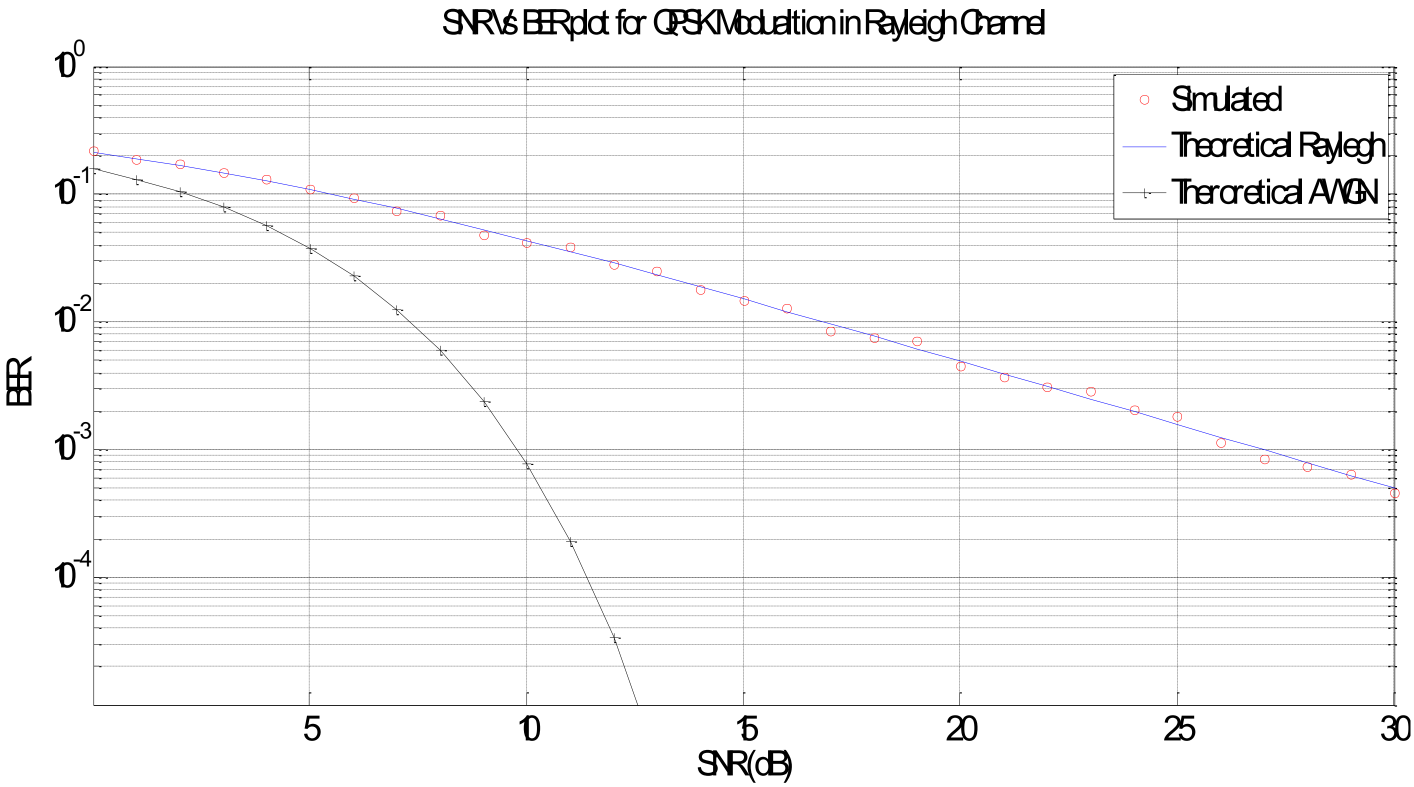
Answer 6

a) AWGN channel (please validate the simulation results with theoretical analysis).
b) Raleigh channel

```
% MATLAB codes for the bit error rate (BER) evaluation of a quadrature
% phase shift keying (QPSK) system operated in a
% a. AWGN channel
% b. Raleigh channel

clear all;
close all;

format long;

% Length of frame
bit_count = 10000;

% SNR range over which we are simulating
Eb_No = -3: 1: 30;

% Convert Eb/No values to channel SNR
SNR = Eb_No + 10*log10(2);

% main calculation loop
for aa = 1: 1: length(SNR)

    % Initialize variables
    T_Errors = 0;
    T_bits = 0;

    % go on until you get 100 errors
    while T_Errors < 100

        % Generate some information bits
        uncoded_bits  = round(rand(1,bit_count));

        % Split the stream into two streams, for Quadrature Carriers
        B1 = uncoded_bits(1:2:end);
        B2 = uncoded_bits(2:2:end);

        % QPSK modulator set to pi/4 radians constellation
        qpsk_sig = ((B1==0).*(B2==0)*(exp(i*pi/4))+(B1==0).*(B2==1)...
            *(exp(3*i*pi/4))+(B1==1).*(B2==1)*(exp(5*i*pi/4))...
            +(B1==1).*(B2==0)*(exp(7*i*pi/4)));

        % Variance = 0.5 - Tracks theoritical PDF closely
        ray =
sqrt(0.5*((randn(1,length(qpsk_sig))).^2+(randn(1,length(qpsk_sig))).^2));

        % Include The Multipath
        rx = qpsk_sig.*ray;
```

```
        % Noise variance
        N0 = 1/10^(SNR(aa)/10);

        % Send over Gaussian Link to the receiver
        rx = rx +
sqrt(N0/2)*(randn(1,length(qpsk_sig))+i*randn(1,length(qpsk_sig)));

%---------------------------------------------------------------

        % Equaliser
        rx = rx./ray;

        % QPSK demodulator at the Receiver
        B4 = (real(rx)<0);
        B3 = (imag(rx)<0);

        uncoded_bits_rx = zeros(1,2*length(rx));
        uncoded_bits_rx(1:2:end) = B3;
        uncoded_bits_rx(2:2:end) = B4;


        % Calculate Bit Errors
        diff = uncoded_bits - uncoded_bits_rx;
        T_Errors = T_Errors + sum(abs(diff));
        T_bits = T_bits + length(uncoded_bits);

    end

    %Calculate Bit Error Rate
    BER(aa) = T_Errors / T_bits;

end

%------------------------------------------------------------


% Finally plot the BER Vs. SNR(dB) Curve on logarithmic scale
% BER through Simulation
figure(1);
semilogy(SNR,BER,'or');
hold on;
xlabel('SNR (dB)');
ylabel('BER');
title('SNR Vs BER plot for QPSK Modualtion in Rayleigh Channel');

% Rayleigh Theoretical BER
figure(1);
EbN0Lin = 10.^(Eb_No/10);
theoryBerRay = 0.5.*(1-sqrt(EbN0Lin./(EbN0Lin+1)));
semilogy(SNR,theoryBerRay,'b');
grid on;

% Theoretical BER
```

```
figure(1);
theoryBerAWGN = 0.5*erfc(sqrt(10.^(Eb_No/10)));
semilogy(SNR,theoryBerAWGN,'k-+');
grid on;
legend('Simulated', 'Theoretical Raylegh', 'Theroretical AWGN');
axis([SNR(1,1) SNR(end-3) 0.00001 1]);
```



Answer 7

Frequency Shift Keying (FSK) **advantage** over Phase Shift Keying (PSK):
FSK has lower probability of error (Pe).

Frequency Shift Keying (FSK) **disadvantage** over Phase Shift Keying (PSK):
FSK uses larger bandwidth compared to PSK. Hence it is not bandwidth efficient.

Reason why CPFSK is preferred over FSK:
CPFSK is constrained to maintain continuous phase at its symbol time boundaries. This constraint offers important advantages in error rate performance as well as signal spectrum containment. Also, continuous phase is desirable for signals that are to be transmitted over

a bandlimited channel, as discontinuities in a signal introduce wideband frequency components.

How could the continuous phase be achieved?
The FSK is memory less process. No record is kept for symbol to symbol accumulation. In case of CPFSK, the phase is accumulated from symbol to symbol to maintain a smooth phase transition. This is how a continuous phase is achieved.

Answer 8

20dBW =100 W

$$f = 800Mhz, \lambda = {}^{c}\!/_{f} = {}^{3e8}\!/_{8e8} = 0.375$$

$$P_r = P_t G_t G_r \frac{h_r^2 h_t^2}{d^4} = 100 \times 0.019953 \times 0.001 \times \frac{30^2 \times 1.7^2}{(20 \times 1000)^4} = 3.244 \times 10^{-17} = -134.89dBm$$

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} = \frac{100 \times 0.019952 \times 0.001}{(4\pi)^2 \times (20 \times 1000)^2} = 3.1587 \times 10^{-14} = -105.005dBm$$

Answer 9

Survey on: *Smart Antennas and Beamforming*

Papers used for this survey report:

1. Smart Antennas in Wireless Communications: Base Station Diversity and Handset Beamforming
   By: *Naflali (Tuli) Herscovici, Christos Christodoulou, Carl B. Dietrich, Jr., Warren L. Stutzman, Byung-Ki Kim, and Kai Dietze*
   From: *Virginia Tech Antenna Group, Electrical and Computer Engineering Department, Blacksburg*
2. Sequential Studies of Beamforming Algorithms for Smart Antenna Systems
   By: *S.F. Shaukat, Mukhtar ul Hassan, R. Farooq, H.U. Saeed and Z. Saleem*
   From: *Department of Electrical Engineering, COMSATS, Abbottabad, Pakistan 1 Brunel University, Uxbridge, United Kingdom (UK)*

Introduction

Smart Antenna in the field of wireless mobile communication has attracted a huge amount of interest from all over the world in recent years. The demand for wireless communication has risen rapidly in the last few years with increasing access of internet and multimedia file sharing.

In order to meet this demand, the limited capacity systems like Single input single output(SISO) are being considered to be replaced by systems like Mutiple Element Antenna(MEA). The benefit of using multiple antennas is increase in communication reliability, rapid increase in data rate by spatial multiplexing etc.

A smart Antenna can reduce noise and therefore very promiing in reducing signal to noise ratio and also enhance the capacity of the system. They have only been considered for base stations so far. Smart antennas operate by processing signals induced on an array of antennas. Hence, they have applications in the field of radar, medical image location dependent applications and sonar. The most important property of smart antennas is spatial filtering. This means the smart antennas can receive energy from one direction while at the same time block energy from other directions.

Some rescarchers have proposed diversity combining at the terminals (i.e., the handheld radios), and have shown that significant performance gains can be achicved. The use of adaptive antciiiias on handheld radios is a new area of research. 111 1988, Vaughaii concluded that with thcn-current technology, adaptivc beamforming was feasible for units moving at pedestrian speeds, but not for high-spced mobilc units. Lian suggestcd tlie use of handheld arrays in mobile satellite systems. In 1999, Braun et al. reported on indoor experiments in which data were recorded using a stationary narrowband transmitter and a two-element bandheld receiving antenna array. In data recorded over different paths were treated as desired and interfering signals, antl the uncorrupted desired signal-unavailable in practice-was used as a rcfercnce signal for optimum heamfonning. While thcsc experiments do not corrcspond to actual operating condition, interference rejection of 24dB in single interferer case and 16dB in the two-interferer case was reported in two handset configurations.

Diversity combining

Antenna arrays provide with signals that can be grouped together by making use of diversity techniques in order to improve performance in the fading channels. Figure 1 depicts the techniques that can be used for diversity combining. Figure 1a is the simplest of all three methods and is called selection diversity. From a collection of M-antennas, the branch having largest signal to noise ratio is chosen and connected to the receiver. As one would expect, the larger the value of M, the higher lhe probability of having larger signal-to-noise ratio (SNR) at the output. Figure 1b shows this configuration where all M branches are weighted by their respective instantaneous signal-voltage-to-noise ratios. The branches are then co-phased prior to summing, in order to ensure that all branches are added in phase to have maximum diversity gain. As shown in figure 1c, a variation of maximal-ratio combining is equal-gain combining. In this kind of arrangement, each branch is set with the same value of gain, and the value is not changed therearter. As with the previous case, the output is a co-phased sum of all the branches.

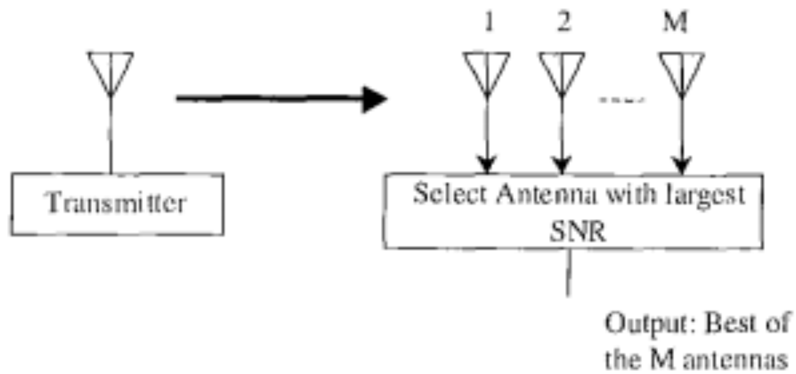


figure 1a

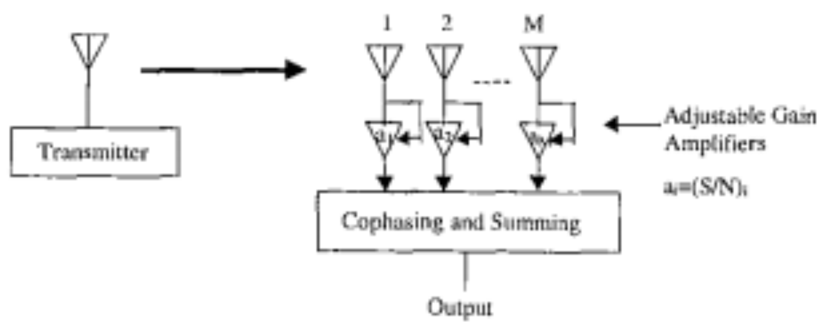


figure 1b

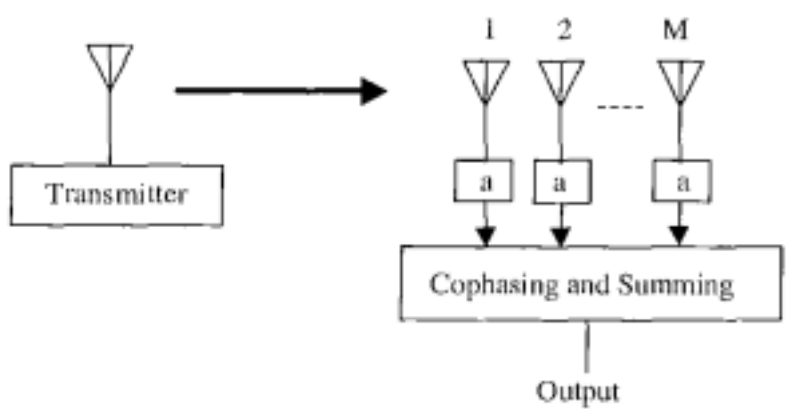


figure 1c

Beamforming techniques

Some array applications, in order to cover a specific angular section, require several fixed beams. Two most common fixed beamforming techniques use either a Butler Matrix or a Blass Matrix.

Butler matrix is a beamforming network that makes use of a combination of 90" hybrids and phase shifters. An 8 x 8 Butler matrix is shown in figure 2a. The Butler matrix makes use of a spatial fast Fourier transformation, and provides with 2" orthogonal beams.

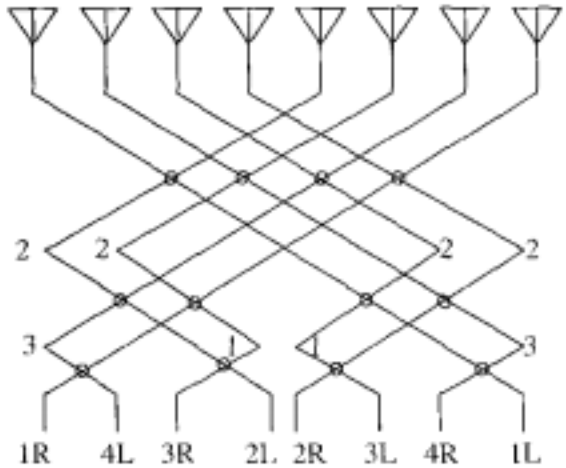


figure 2a

Blass matrix uses transmission lines and directional couplers to form beams by means of time delays, and thus is appropriate for broadband operation Figure 2b shows an example for a three-element array, but a Blass matrix can he designed for use with any number of elements. Port 2 provides equal delays to all elemcnts, rcsulting in a broadside beam The othcr two ports provide progressive time delays between elements, and producc bcams that are off-broadside.

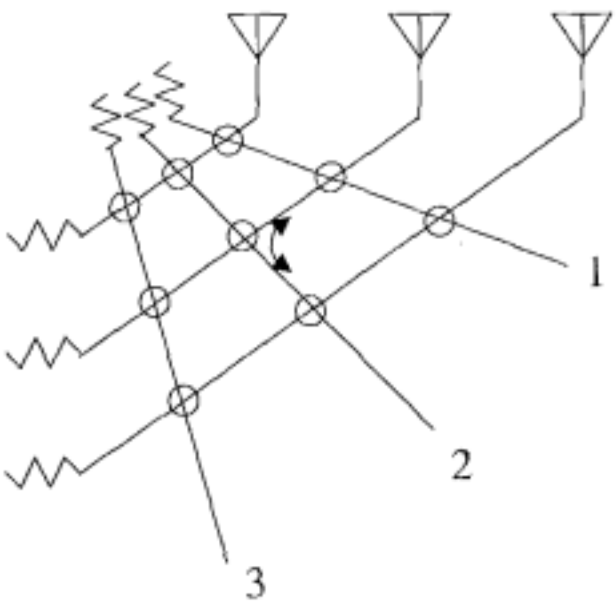


figure 2b

Optimum Beamforming

Complex weights for each elcment of an array can be calculated to optimize some property of the received signal. This does not always result in an array pattern with a beam maximum in the direction of the desired signal, but does yield the optimal array output signal in terms of the minimum mean squared error (MMSE?), or the maximum signal-to-interference-plus-noise ratio (SINR). Most often, this is accomplishcd by forming nulls in the directions of intcrfering signals. Adaptive beamforming is an iterative approximation of optimum beamforming. A general array, with adjustable element weights, is shown in block-diagram in Figure 3a.

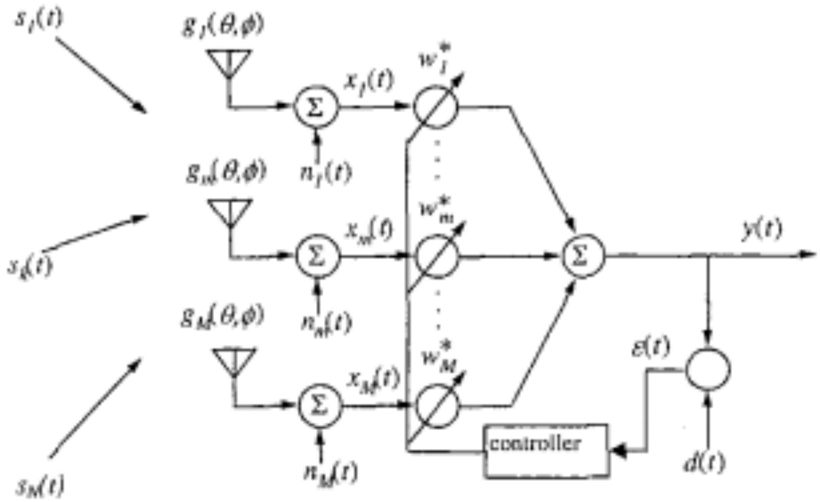


figure 3a: An Adaptive Antenna Array

Smart Base station testbed at Virgina Tech

There is a smart base station hardware located at Virginia Tech. It consists of a mobile transmitter operating at 842 MHz in the cellular band and a base station at the rooftop working as a receiver. The recciver has eight channels connectcd to three types of base-station antcnnas, as listed in Tablc below, along with assigned channel names. In Table 1, S stands for antenna for “spacc diversity,” P stands for “polarization diversity,” and A stands for “angle diversity.” S1 is used as a referencc channel through the measrcmcnt and calibration process.

		At 665 m			At 935 m			At 2,670 m		
Pol.	CDF	S	P	A	S	P	A	S	P	A
V	10 %	5.15	4.45	3.61	4.83	4.61	3.07	5.52	4.65	1.50
	1 %	8.91	8.42	8.72	8.86	8.19	7.79	10.24	8.47	6.33
H+	10 %	5.23	3.82	2.54	5.06	5.19	2.18	5.52	5.12	0.86
	1 %	9.70	6.59	8.26	9.79	10.12	6.06	10.72	9.74	4.62
H‖	10 %	5.65	5.13	3.61	5.08	4.50	2.96	5.65	5.07	1.72
	1 %	10.88	8.91	8.97	9.34	8.47	7.59	9.99	9.41	6.63

Table for measured diversity gain

The 4 x 30-degree pancl anteiina (AI, A2, A3, and A4) covcrs 120". as shown in Figure 3a; the sector antennas (SI, S2) cover 95"; and thc (plus-minus) 45 degrees slanted dual polarized antcnna (PI, P2) covcrs 90 degrees. All have a vertical bandwidth of about 15 degrees. Thc 90" antl 95" azimuth bcamwidth of the dual-polarized and scctor anlcnnas can be considered to be identical, for all practical purposes. Thc two sector antcnnas (SI, S2) arc used for space diversity. The 4 x 30-degree panel antenna (AI to A4) is used for angle diversity, and the dual-polarizcd antenna is for polarization diversity. In order lo obtain high diversity gain, low correlation and powcr balance arc important. Spacc diversity requires wide separation bctwccn two antennas to achieve a low correlation hetween the signals. Tlic (plus minus) 45 degrees slanted dual-polarized antenna is known to have highly balanced power.

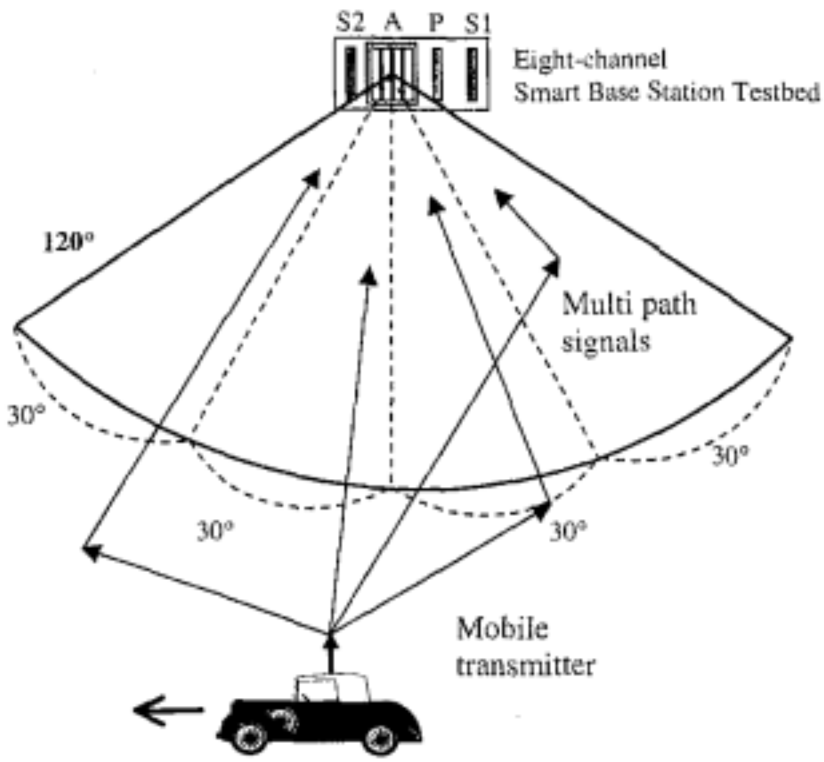


Figure 3a
An eight-channel smart base-station testbed for space, polarization, and angle-diversity comparisons in a multipath environment.

Conclusion

If we do a comprehensive comparison among all the adaptive algorithms, the parameters of beampattern, error plot, amplitude response, and BER have been analyzed. The whole system has also been analyzed in a very strict SNR environment. The significance of LMS algorithm cannot be ruled out in generating better main lobe in a specified direction of user but to nullify co channel interference it plays very unsatisfactory response. CMA has maximum error but if we consider co channel interference it gives more satisfactory and reliable results than LMS and RLS. Results obtained from simulation assert that capability to reject the interfering signal by placing nulls in undesirable direction is really accomplished by CMA. But when angle of arrival of interference and user were quite close to each other then CMA had BER even more than single antenna element. RLS algorithm involves more computations than LMS, it provides safe side towards main lobe and have better response towards co channel interference. It has been revealed as well that convergence rate of RLS is faster than LMS. RLS Algorithm is found to have minimum BER and error signal magnitude, therefore it has been proved the best algorithm for implementation on Base Station Smart Antenna System.

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