THE DIFFERENCE IN NATURE OF RADIO-WAVES, MICROWAVES AND INFRARED WAVES

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THE DIFFERENCE IN NATURE OF RADIO-WAVES, MICROWAVES AND INFRARED WAVES.

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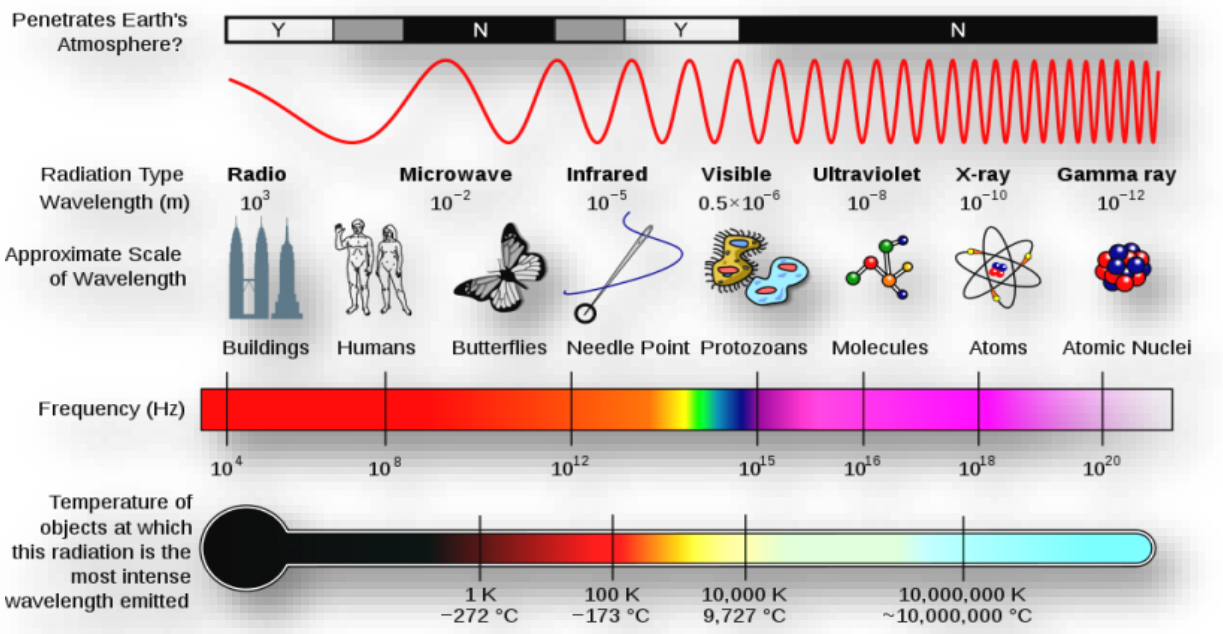
Abstract

Radio waves, Microwaves and Infrared are all different types of wave occurring in different parts of the electromagnetic spectrum and are majorly used so this paper will describe the difference between the characteristics of these three.



These three are all waves with different applications but since there uses and their upcoming technology is advancing there should be a clear differentiation of all these three waves based on different parameters and all aspects. I will start by introducing each wave one by one which will give us a rudimental start and later ahead in the paper we will see more technical and functional variances.

[1] I am a B. Tech graduate from Reva university Bangalore and my area of specialization is electronics and communication, my area of interest and research is microwave and communication.

ELEMENTARY DIFFERENCES BETWEEN RADIO WAVES, MICROWAVES & INFRARED WAVES

I. Radio Waves

Radio waves are EM waves with Frequency in the range of 3KHz to 1GHz and they are easily generated by passing electric current through a conductor and when the field is formed transferring that field via an Open surface conductor (Antenna) to a receiver that can Take in that Wave and convert it into electrical current again.

Radio waves have relatively larger wavelength thus they travel to long distances and can penetrate walls, building etc. without much '*diffraction*'[2] or '*fading*[3]'. Radio waves are omnidirectional i.e. they can travel in any direction after getting ejected from antenna thus making them very efficient and directive. These qualities make radio wave's application horizon hugely broad as it is seen everywhere, from a confined building as Wi-Fi Signal to the extent of Radio waves being used in the world for broadcasting as the invention of the millennium which is the *Transistor Radio* which is named after this wave as the signals of transmission for different radio stations signals are radio waves.

But there are certain cons with a lot of pros and those are:

a) The frequency of Radio wave is limited as compared to the others so it is only used in applications which don't involve robust transmission so usually employed in indoor environment like a home or office as WLAN (Wireless Local area network) or used within a limited region as Radio station's transmission signal.

b) Another Drawback of the radio wave is that it can only penetrate walls and avoid diffraction at lower frequencies if the frequency is increased towards the maxima the wave bounces back.

c) Radio waves have a lot of diffraction and attenuation as compared to microwave and infrared.

d) Bluetooth nowadays is a better alternative than radio as it is easier to connect and operate it is proven to be even more secure and requires lesser infrastructure.

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[2] *Diffraction is the reflection of a signal when it hits a solid or sharp object this causes the signal to attenuate and it loses its signal strength.*

[3] *Fading it defined as the gradual variation decrease of a signal strength when the distance between receiver and transmitter is quite large and the receiver is not getting robust signal.*

II. Micro Waves

Microwaves are Electromagnetic waves which have frequency between 1 to 300 GHz they are used in everyday life for communication as they can travel long distances, being unidirectional they have to travel at LOS (Line of Sight).The frequency coverage of microwaves is huge so there are conventional band allocated for referring to the frequencies in microwave range, the bands start from L to the last *mm* [4]band.

Microwaves have become an integral part in our everyday technology driven life like Calling, high speed Data Access and most importantly connecting the whole wide world together via satellite communication and to the most laid-back use such as heating our food. Microwaves are called as microwave's not because of their wavelength (it's of the order 30cmm to 1 mm) but because their wavelength is smaller than the pre-existing wave i.e. Radio wave.

But as everything good thing comes with a pinch of imperfections and thus microwave communication also has its fair share of flaws and that are:

a) Microwaves easily get dislocated and fade away if the line of sight is disrupted by an obstacle.
a) Signal absorption acts as a hindrance for microwave communication as sometimes it suffers microwave losses also.
b) Microwave communication requires a huge apparatus and infrastructure (like towers, antennas etc) which eventually requires a large investment, so it is costlier than other type of communication.
c) Microwave Transmission lines and circuits are difficult to analyse and conventional circuits cannot be used.
d) Microwave signals require large bandwidth and the signals can be bugged, so the mode of communication is not secure.
e) Because these waves travel large distance, they encounter power losses which can be compensated by large signal strength and frequency but we still need to balance the impedances to reduce excess power loss.
f) Still technological advancement is going on in the field microwave for better communication and deployment.

[4] *mm refers to millimetre wave band which is the last band with frequency of 110 to 300GHz.*

III. Infrared Waves

Infrared waves usually called as '*IR*'[5] is an enormously high frequency wave and its wavelength is very near to visible colour light spectrum still humans cannot see it but they feel it in the form of heat but some high range infrared waves can be seen by humans as red light. Circuits and machines producing heat waves, object detection systems etc. use infrared wave as communication source.

The principle of infrared communication is that it produces high frequency pulses which cannot be used for long ranges but for short ranges (up to few meters) these pulses perform reflection from source points. Taking an everyday life example of a TV remote control which has an IR blaster at the top so when we press a button the signal is transmitted through the IR blaster to the TV's photodiode which is the receiver IR Receptor of the TV and just like an acknowledgment that transmitted wave is reflected.

The power required for IR transmission is very less and the signal cannot be bugged as the IR communication is usually confined in small enclosure's like a room. The IR communication is fast and is not attenuated & dissipated easily it is proved to be best method of communication in short range communication and one doesn't need any licence for infrared communication or for its devices.

But there are multiple shortcoming's related to IR communication because of its limited use and those are:

a) Infrared waves can only travel short distances because of signal degradation at larger distances so cannot be used for long range communication.
b) Infrared waves get affected by hard objects like doors, walls, furniture etc. and even by particulate matter like dust, smoke, sunlight etc.
c) We can control only one object at a time which works on infrared and the it only works if the path of communication is LOS.
d) The data rate of infrared wave communication is very low nearly 115kbit/sec which is very less.
e) Infrared use can be harmful as the Infrared waves can damage eye's and the radiation in the waves has heat which if used extensively can cause skin disorders.

[5] *IR here is an acronym for infrared which will be used across the paper multiple times.*

OPERATIONAL DIFFERENCES BETWEEN RADIO WAVES, MICROWAVES & INFRARED WAVES

As we have discussed earlier the wavelength of all these waves are different which are:

- Radio Wave:3m to 0.3 mm
- Micowave:30cm to 1mm
- Infrared wave:0.7 to 2.5 µm

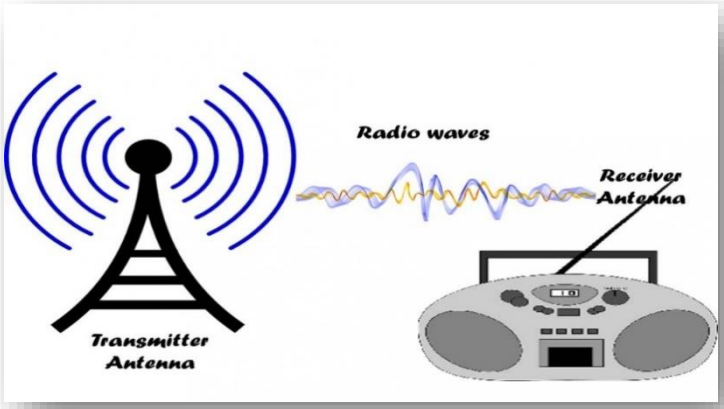
So, we can observe that their frequency and wavelength differ subsequently accordingly their generation and reception also differ from one another, now we will see in detail below for each type as how they are generated and transmitted.

I. Generation and Transmission of Radio Waves

Radio waves are composed of 2 parts i.e. message part and carrier part ,the message part is usually our voice or any audio sample that has to be transmitted and that is when carrier part comes into picture it is an information less signal which is just required to increase the signal strength, this phenomenon of increasing signal strength is called as 'modulation'.

Modulation is done primarily in order to increase the signal strength and for many additional reasons like multiplexing, reducing antenna height, giving every signal an individuality etc. Modulation is a process in which we overlap the properties of our message signal on to the self-created carrier signal which is information less.

There are multiple types of modulation but usually analog modulation and frequency modulation is used in RF communication. To churn things down better I will present an example of FM radio transmission for better understanding of this concept and for the generation and transmission.



As we know the radio stations transmit their signals using radio wave communication, the audio samples, voices or songs are recorded and are modulated with the help of analog or frequency modulator which is present in their premise of the radio station itself, the modulated signal is then transmitted through huge parabolic dish antennas. The listeners who tune to the frequency of that particular radio stations can receive the signal via a respective type of antenna (depending on the receiving device).

The voice or audio signals which are message signals have a very low frequency (of the range of certain Khz) but the carrier which is the radio wave has a large frequency of around hundreds of MHz which helps in the transmission. So, the frequency which we hear as the name of radio stations name is in fact the frequency of carrier signal so if a radio station is let's say *96.5* that is the carrier frequency of the radio wave (in MHz).

The modulator is a circuit which multiplexes the message and amplifies the signal to such an extent that a desired high frequency is produced. Radio waves in nature are actually produced because of magnetic field shift and creation of an EM wave which has high frequency but modulator circuits are preferred for producing it artificially for different purposes.

II. Generation and Transmission of Microwaves

Microwaves are produced in a very different way than radio waves are, there are definite methods and apparatus that are used for the production of microwaves but the transmission of these waves is still dependent on antennas. The medium or channel of microwave communication is air, as transmission lines cannot be used at such a high frequency because of '*skin effect*'[6], After an enormous analysis of microwaves being transferred through transmission lines we analyse two things firstly that microwaves are hyperbolically trigonometric in nature and secondly that two waves move simultaneously one transmitted and one reflected, the reflected waves comes back to the transmitter side and the reason is '*Impedance mismatch*'[7]. So, we have to take this fact into consideration and we need to balance

[6] Skin effect is a phenomenon which is observed in high frequency carrying cables like coaxial cable it states that even the best conductors have a drop of 30% in their conduction because carrying high frequency signals increases the surge capacitive impedance of the cable/wire.

[7] Impedance mismatch is observed when the impedance at the load side is not equal to the source side or vice versa which is the converse of maximum power transfer theorem, so the power is transferred partially and thus power is wasted and reflected back.

the impedance on the transmitter and receiver side or else a lot of power is wasted because of reflection.

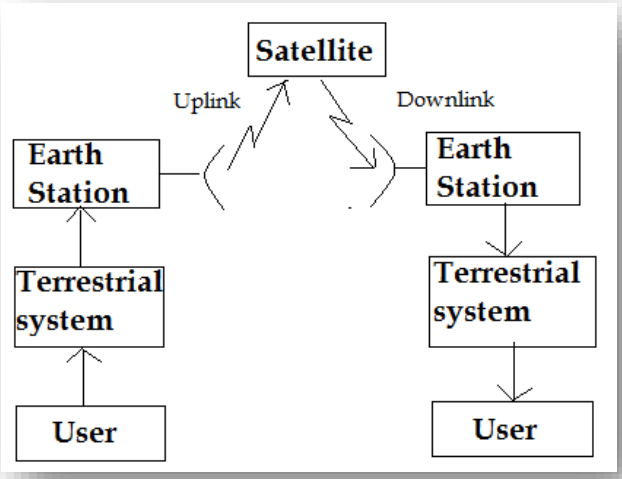
Microwaves are generated by large devices like; Multi-cavity klystron, travelling wave tube, reflex klystron and is also generated and amplified by small semiconductor diodes like; Gunn diode, Tunnel diode, PIN diode, Schottky diode etc. & By avalanche devices like IMPATT, TRAPATT & BARITT.

The principle of all the devices stated above is almost similar as all of them just create an EM wave and amplify it to a frequency of microwave range by their different operating principles, for generating a signal we need an oscillator which is a device that takes in voltage and converts it into radiation/signals which can be further amplified to produce microwaves. Some majorly used microwave oscillators are Magnetron & backward wave oscillator. Some semiconductor devices mentioned in the above paragraph are also oscillators.

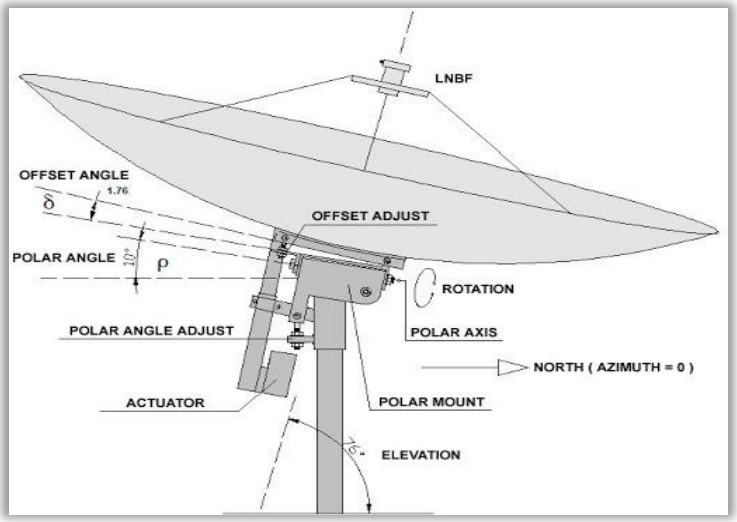
Microwaves acquires a huge bandwidth and so are its applications and these different applications require different generation and transmission methods, unlike radio wave communication microwave communication does not use analog or frequency modulation but it requires a combination of a digital modulation technique and a multiple access technique for distribution of data among all the users.

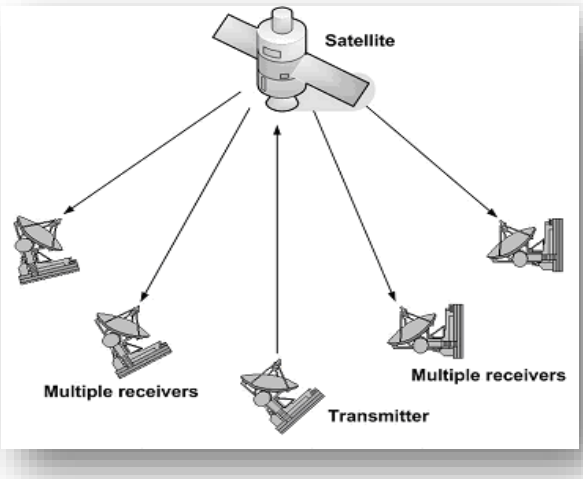
Digital modulation techniques are techniques which are used for modulation of digital signals like binary signals some examples are: ASK, PSK, FSK, QPSK, QAM and multiple access techniques are distribution mechanisms used for the distribution of the transmitted waves among the receivers/users and a correct technique has to be employed so that all the users can efficiently utilize the data or waves transmitted. Majorly used multiple access techniques are TDMA, FDMA & CDMA. As an instance the mobile communication which we are engage in our day to day life is employed with WCDMA(3G) or OFDMA(4G) technique where users can access the data all the time with maximum frequency as the data is coded and transmitted using spread spectrum.

To cover all the concepts of microwaves I will take the example of satellite communication in satellite communication the satellite is controlled and data is monitored from an earth station, as we know the distance between earth station and satellite transponder is very large the signal frequency should also be large enough so that it can reach the distance and should have high data rate.



These high frequencies are microwave range frequencies consequently they will operate in LOS (Line of sight) to establish that an arrrangment is available in the antenna with which we can adjust the angle of transmission according to the position of the satellite,these antenna are termed as polar mounted antenna which are majorly used in earth stations.





The data sent from earth station is called as '*uplink'* [8] has to penetrate all the layers of atmosphere and has to reach the satellite at a LOS. The uplinks are amplified using 6 cavity klystron tube and it is transmitted through large '*parabolic reflector'* [9]antennas which reach the satellite transponder and then transponder distributes and sends the data to earth stations and other receiving stations which is called as '*downlink'*[10].

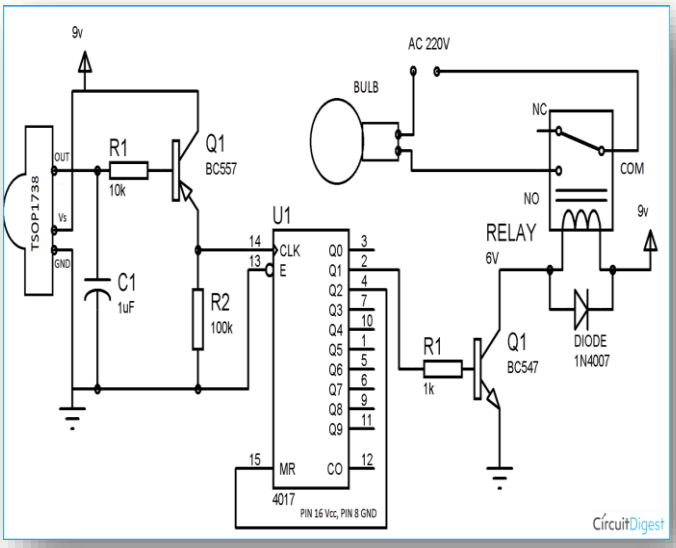
[8] Uplink is message sent from the earth station to the satellite for controlling or modifying the aspects of the satellite.

[9]Parabolic reflector is huge dish shaped antenna that have high directive gain.

[10] Downlink is the message that is sent from the satellite transponder to the earth station it has all the data of remote sensing or the signals which are projected for transcoding/division.

The uplink is usually of 14 GHz and downlink is of 12 GHz which is expressed as 12/14. The modulation technique which is employed is QAM (quadrature amplitude modulation) and the multiple access technique used is FDMA (Frequency division multiple access). The uplink which reaches the satellite is divided according to bandwidth and no. of users then is sent to the receivers so the combination of FDMA and transponder actually act as '*Demultiplexer*[11]' for the uplink.

III. Generation and Transmission of Infrared Waves



Infrared waves as mentioned previously are high frequency waves which are emitted as high-speed pulses so there is no fixed method for producing infrared it is produced by the circuits itself. Infrared waves have the frequency range of 300 GHz to 300 THz, none of the apparatus available are capable of producing such high frequency waves therefore the machines and circuits producing IR are designed in such a way that they emit these high frequency pulses but for a short period of time, using static DC voltage.

IR finds its major application in remote controls as it requires an instant control, in every remote controller you will find that there is an IR LED which emits radiation in the form of light. Also, the emitted light from a photodiode or an IR LED has very high frequency and the pulsar emission causes major photon ejection which in turn produce heat so the IR wave have heat and thermal properties also.

This radiation in a controller is nothing but the flow of a control signal which has some control message associated with it which is monitored by a small microcontroller placed in the circuit of the remote which is controlled by the user, as he presses a respective button the control signal is converted into a

[11] Demultiplexer is a digital circuit which takes a single input and divides it into multiple signals.

digital signal and is transmitted through the IR LED (or often called as IR blaster) to the IR receiver present on the controlled appliance and it receives that signal and coverts it into electrical signal and the desired task is executed in the controlled device a circuit diagram is shown above for reference, these circuits are easy to make and are nowadays available in smart phones also to control an entire range of appliances by your phone itself.

There are other IR operated circuits like temperature detector, proximity sensor, liquid level indicator etc. all these circuits also use the same principle for generation of IR waves but their fundamental operation differs based on their operation. In these circuits the IR is generated by the circuitry as mentioned earlier but IR is generated in nature also by sun, and other natural electromagnetic forces.

So, in conclusion, IR waves are not used for long range communication but are used for controlling and thermal heating related purposes mostly and it is only successful if the transmitting and receiving devices are in proximity and in LOS.

TECHNICAL DIFFERENTIATION BETWEEN RADIO WAVES, MICROWAVE & INFRARED WAVES

Characteristics	Radio Wave	Micro Wave	Infrared Wave
Communication uses	Used for long range and point to point communication	Used for long and extra long-range communication	Not used for any high range communication but used for short range control
Directivity	Omnidirectional	Unidirectional	Unidirectional
Security	Least Secure	Secure	Highly Secure
Usage Cost	Requires a lot of infrastructure so usage cost is large.	Requires more infrastructure and apparatus than radio waves so usage cost is largest.	Requires minimal infrastructure usually an electronic circuit so usage cost is least.
Extent of penetration	Can penetrate large walls and solids but at low frequency only.	Can penetrate large walls easily but there is a diffraction that occurs.	Cannot penetrate large walls.
Licencing	Government licence is required to operate.	Particular range of frequencies in microwave require a government licence to operate.	No government licence is required to operate and construct infrared based device.
Attenuation	High	Moderate	Low

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