© December 2017 | IJIRT | Volume 4 Issue 7 | ISSN: 2349-6002

Survey paper on Radio Microphone

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Abstract- **The area of information and communication technologies is one of the fastest changing areas, with related services and applications having enormous and almost immediate impact on diverse aspects of the modern society, including inter-human relations, economy, and education and entertainment. This paper describes about different types of microphones, difference between the analog and digital radio microphone and applications.**

Index Terms- **Radio Frequency (RF), Frequency Modulation (FM), ultra high frequency (UHF)**

I. INTRODUCTION

Conventional wired microphones convert sound into an electrical audio signal that is sent to the sound system through a cable. Live music stages that are crowded with cables from microphones for vocals, guitars, drums and other instruments can become a snake pit of overlapping wires and limit the performers‘ freedom of movement on the stage. Wireless microphone systems convert audio signals created by microphones into radio signals, which are sent by a transmitter through the air to the receiver and then through the sound system.

A wireless microphone is a microphone without a physical cable connecting it directly to the sound recording or amplifying equipment with which it is associated. Also known as a radio microphone, it has a small, battery-powered radio transmitter in the microphone body, which transmits the audio signal from the microphone by radio waves to a nearby receiver unit, which recovers the audio. The other audio equipment is connected to the receiver unit by cable. There are many different standards, frequencies and transmission technologies used to replace the microphone's cable connection and make it into a wireless microphone. They can transmit, for example, in radio waves using UHF or VHF frequencies, FM, AM, or various digital modulation schemes. Some low cost (or specialist) models use infrared light. Infrared microphones require a direct line of sight between the microphone and the receiver, while costlier radio frequency models Some models operate on a single fixed frequency, but the more advanced models operate on a user selectable frequency to avoid interference and allow the use of several microphones at the same time. [1]RF is an abbreviation for “Radio Frequency” and is used to describe the range of spectrum utilized for many types of wireless transmissions, including radio, television, mobile phones, remote controls, and wireless microphones. The term “Radio” in its most basic definition is the transmission of electromagnetic waves through space. These electromagnetic waves can vary in length and amplitude and occur naturally all around us. The wavelength is the physical distance between the start of one cycle and the start off the next cycle as the wave moves through space. The rate of the wave is measured in Hertz (abbreviated Hz), or cycles per second. This is called the “Frequency” of the electromagnetic wave. Figure 1 shows a basic guide of electromagnetic waves and their respective frequencies, with radio waves broken out into the lower part of the figure. RF Transmission Radio waves can be used as a method for transmitting information. The most common method used for transmitting analog audio via RF is with Frequency Modulation, or FM. The radio frequency being transmitted is called a carrier wave. This carrier’s frequency is modulated up and down depending on the amplitude of the audio. This technique is used in FM broadcast radio, and in analog wireless microphones. [2][3]

Every wireless microphone system transmits and receives sound on a specific radio frequency, known as the operating frequency. The crucial part in using wireless systems is the right choice of this operating frequency.A wireless microphone system basically features two components:

1. Transmitter
2. Mic/Cable

3. Receiver

The sound is mainly influenced by the microphone capsule. The wireless system should not affect this sound.

II. DIFFERENT KINDS OF MICROPHONES

1. Carbon microphone:

Carbon microphones are the first microphones, which could transmit sound with a reasonably high quality. We should consider carbon microphones the direct prototype of today's microphones. Carbon microphone was invented by Emile Berliner. Alexander Bell bought this microphone technology for starting to produce his phones commercially. This type of microphones used *two* metal plates which were separated by carbon granules. Direct steady current was passed between those two plates through the carbon granules. One of the plates was very thin and was used as a diaphragm. While catching sound it was vibrating making a pressure on carbon granules. While under pressure they were moving closer to each other and the resistance between the plates was lowering. And sound was transformed into varying resistance, which was then transmitted through electrical wires.(Fig 1)

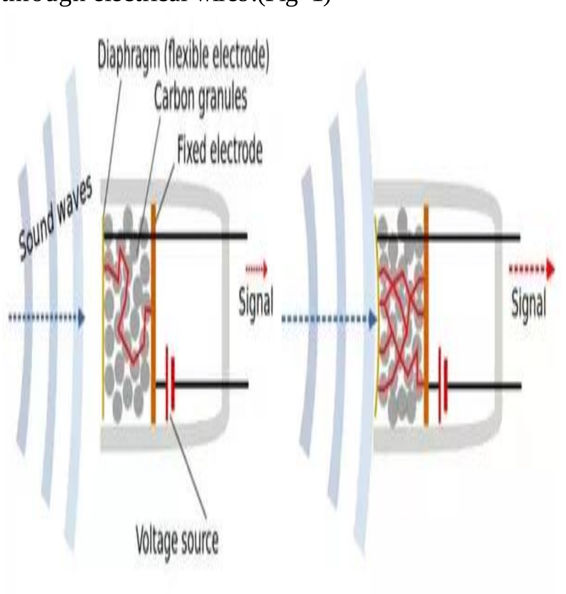

Fig 1- Carbon microphone schematic[1]

This type of microphones was the main one in phones up to the 1980th acquiring some changes through the time, but still being the old good carbon microphone.

2. Dynamic microphone:

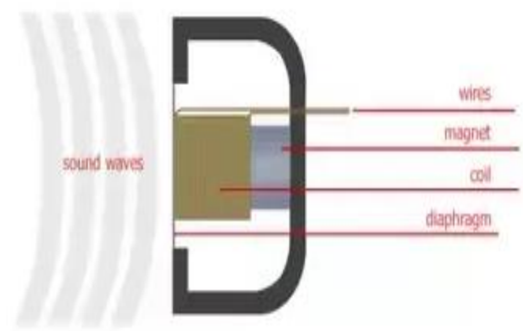

Fig 2 -Dynamic microphone schematic[1]

This type of microphones is also known as moving-coil microphones as shown in Fig 2. It takes advantage of electromagnetic induction effect. A small movable induction coil is positioned in the magnetic field of a permanent magnet. That coil is attached to the diaphragm. When sound creates pressure on the diaphragm, it starts to vibrate. While vibrating it moves the coil in the magnetic field. Such movement produces a varying current in the coil through electromagnetic induction, which can be then amplified and used for transmitting the sound. Dynamic microphones are the ones most commonly used for sound recording and on-stage.

3. Condenser and electrets microphones:

Condenser microphone is generally a capacitor. One of the capacitor's plates is used as a membrane, which moves in response to sound pressure. When it moves, the capacitance of the capacitor changes and after amplifying creates a measurable signal. Condenser microphones require a power source for maintaining the capacitor charge as shown in fig[3].

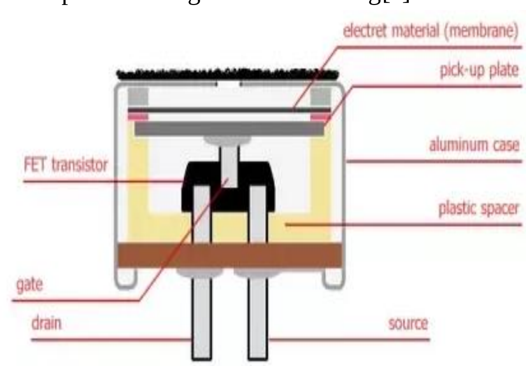

Figure 3- Condenser and electrets microphones[1]

4. Electrets microphone schematic

One of the condenser microphones types is an electrets microphone. Electrets are a stable dielectric material with a permanently embedded static electric charge. Including such a material into the condenser microphone allows to get rid of power source for charging the capacitor. Electrets microphones are usually placed inside an aluminum case. They have a diaphragm made of electret material. Under the diaphragm the pick-up plate is placed, with a small distance between the diaphragm and the pick-up plate. When the sound makes diaphragm vibrate, it changes the distance between the diaphragm and the pick-up plate. This increases the voltage on the gate of the FET connected to the pick-up plate (FET actually requires some external power to be applied to it). When there is no voltage on FET's gate, power between source and drain is not transmitted. But the higher the voltage on the gate is, the more power is transmitted between them. This is the way of creating a signal from electrets microphone.

Electrets microphones are the cheapest ones in terms of production, good in terms of performance and the most widespread microphones.

Electrets microphones were the ones to use in computers, PDAs, phones and smart phones. However, they are rather big and are not that comfortable to mount on the new generation smart phones' PCBs

III. ANALOG RADIO MICROPHONE

Radio microphones can be classified into three types in terms of their transmission technologies. The first is the analog radio microphone and the digital radio microphone. Analog systems utilize proven radio technology that offers quality audio performance and high channel count, even with entry-level systems Research and development on analog radio microphones goes back to the 1980s. At the time, radio microphones were treated as weak radio stations, and most used the 200- or 400-MHz bands. A ministerial ordinance in 1986 placed limitations on the electrical field strength at a distance of 3 m from a weak radio station. In particular, the permitted values for weak radio waves from 322 MHz to 10 GHz could be no more than 35 μV/m. Thus, it became difficult to use radio microphones over 322 MHz as weak radio stations, and for that reason, serious R&D on 800-MHz-band radio microphones began. Radio microphones were studied in terms of three applications, i.e., professional use, general use, and loudspeaker use, and on analog frequency modulation (FM). The Main Technical requirements of analog radio microphone are given in table 1. And the block diagram of analog radio microphone is shown in fig 4.

Table 1: Main technical requirements of analog radio microphones.

Item	Specified radio microphone (Type-A radio microphone)			Specified low-power stations radio microphone (Type-B radio microphone)
Frequency bands used	779 to 788 MHz (till Mar. 31, 2019) 797 to 806 MHz (till Mar. 31, 2019) 470 to 710 MHz (TV white space) 710 to 714 MHz 1,240 to 1,252 MHz 1,253 to 1,260 MHz			806 to 810 MHz
Antenna power	10 mW or less 50 mW or less (1,200 MHz band)			10 mW or less
Communication scheme	Simplex/Duplex			Simplex/Duplex
Modulation	Frequency modulation			Frequency modulation
Compander	No (linear)	Yes	Yes or No	
Occupied bandwidth Permitted values	330 kHz	110 kHz 160 kHz	250 kHz (stereo)	110 kHz
Station permit	Required			Not required
Operational regulation	Required			Not required

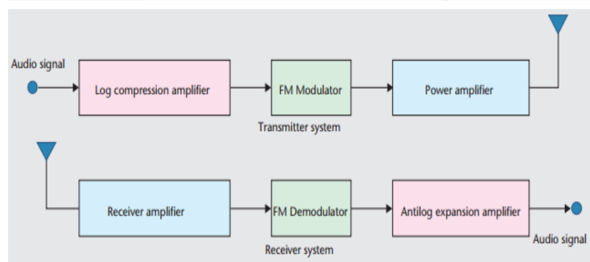

Figure 4: Analog radio microphone overview[4]

The use of a compander, which compresses and then expands the amplitude of the audio signal, was studied for general and loudspeaker radio microphones. A compander puts a log compression amplifier at the transmitter in order to reduce the dynamic range of the modulator input and an antilog expansion amplifier at the receiver, as shown in Figure 4. This results in linear amplification of the overall characteristic. A compander reduces the bandwidth of radio waves needed to transmit the audio signal and the required input power at the receiver. It also produces an improvement in perceived sound quality. However, its transient response can distort audio quality. For this reason, some type-A radio microphones do not use companders7). The main technical requirements for most current analog radio microphones are shown in

Table 1. In the 2012 system revisions, March 31, 2019 is the deadline for switching from the 770-to-806-MHz band to the 710-to- 714-MHz and 1.2-GHz bands. Antenna powers up to 50 mW are allowed in the 1.2-GHz band. The 2012 system revisions also permit an occupied bandwidth of 160 KHz,[4].

IV. Digital Radio Microphone

An overview of digital radio microphones is shown in Figure 5. Single-carrier phase shift keying (PSK) modulations such as QPSK and 8PSK were initially studied with the intention of transmitting an audio signal compressed to approximately 1/5th of its original size at bit rates of 384 to 576 kbps and applying digital processing such as error-correction coding. The occupied bandwidth for phase modulation transmission is equivalent to approximately half of the transmitted bit rate (192 kHz for type B microphones and 288 kHz for type A),[5].

Table 2: Main technical requirements of digital radio microphones

Item	Specified radio microphone (A-type radio microphone))		Specified low-power stations radio microphone (B-type radio microphone)
Frequency bands used	770 to 806 MHz (till Mar. 31, 2019) 470 to 710 MHz (telephone white space) 710 to 714 MHz 1,240 to 1,252 MHz 1,253 to 1,260 MHz		806 to 810 MHz
Antenna power	50 mW or less		10 mW or less
Communication scheme	Simplex/broadcast		Simplex/broadcast
Modulation	Phase modulation, frequency modulation, quadrature amplitude modulation, orthogonal frequency division multiplexing		Phase modulation, frequency modulation, quadrature amplitude modulation
Occupied bandwidth Permitted values	600 kHz (1,200 MHz band only)	288 kHz	192 kHz
Station permit	Required		Not required
Operational regulation	Required		Not required

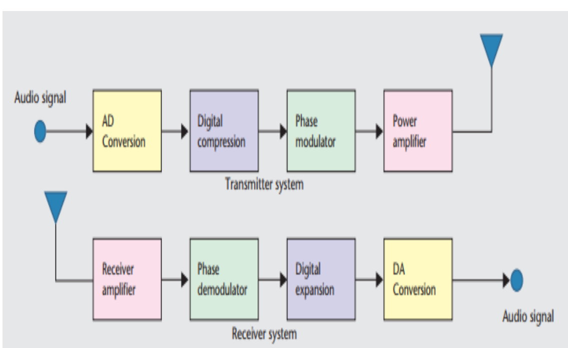

Fig 5: Digital radio microphone overview [4]

V. ADVANTAGES OF DIGITAL MICROPHONE

1.Superior Sound Quality

Digital wireless systems offer highly transparent audio quality. This is largely due to the lack of a "compander," a circuit used in all analog wireless microphone systems to minimize noise and maximize dynamic range. (Compander is a contraction of the words compressor and expander.)The audio signal is compressed in the transmitter to accommodate the limited dynamic range of FM radio and then expanded in the receiver. This process, while relatively imperceptible in most good analog systems, can still lead to audible artifacts (like "pumping" and "breathing") that make a wireless microphone sound different from its wired equivalent. Since the transmission of a digital audio signal doesn't require companding, the received signal retains the exact characteristics of the original audio input.

A digital wireless system can also achieve a flat frequency response across the entire audible range (20 Hz to 20kHz), which yields the truest possible sound transmission. The microphone element, not the "wireless" components, more closely defines the frequency response of the system. Digital wireless systems convert analog audio to a digital signal that modulates a radio carrier in discrete steps (think ones and zeroes). The digital audio signal arrives at the receiver unaffected by the radio link. Any RF noise that may be present below a certain threshold doesn't affect the audio quality. The receiver simply ignores anything that isn't a zero or a one. Everything else is discarded. Only the digital signal is sent on for amplification,[6].

2.Longer Battery Life:

In general, digital wireless microphone systems have 30–40% longer battery life than equivalent analog systems.

3.Better Spectral Efficiency

While this isn't necessarily true of all digital wireless systems, the modulation type chosen by the manufacturer can potentially lead to much higher channel counts in reduced clear spectrum. The deviation of a digital wireless signal is more predictable than that of a frequency-modulated analog signal, allowing tighter channel-to-channel frequency spacing. This feature is particularly important in light of the continued crowding of the UHF television band where many wireless microphones operate. Depending on the manufacturer and model, digital systems can often deliver nearly twice the channels in the same slice of spectrum as their analog cousins.

4. Audio Latency

Audio latency has an effect on musical performances. The sound from the mixing board is actively sent back to the performers through the in-ear monitors, making the delay requirements much more stringent. Performers are able to hear their own voices or instruments directly and when this live sound is mixed with delayed sound from the in-ear monitors, it has an effect on the sound quality felt by the performer. As a preliminary part of developing the low-latency specified digital radio microphone, we checked this effect by evaluating the detectable limits of delay in the audio monitors and their effects. We found that if the delay of the entire system is 3 ms or less, there is generally no problem, but if the delay exceeds 5 ms, 80% of performers noticed the delay10). In real environments, a radio microphone, mixing board and in-ear monitor are used together, as shown in Figure 6. Most modern mixing boards are also digital, so they introduce a delay of approximately 2 to 3 ms. Thus, if the delay of both the radio microphone and the earphone monitor can be kept to 1 ms or less, the overall system delay can be kept to 5 ms or less.

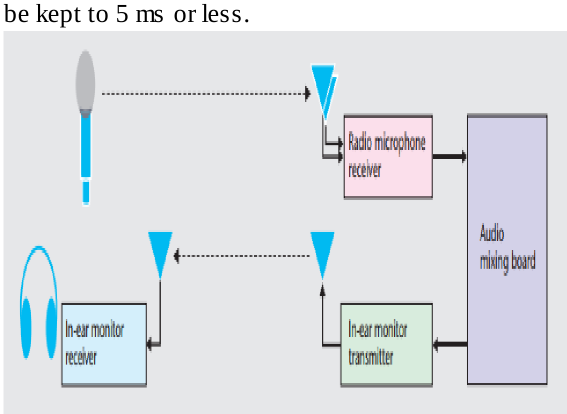

Fig 6: Radio microphone and (earphone) monitor[4]

VI. TRANSMISSION FORMAT FOR LOW-LATENCY SPECIFIED DIGITAL RADIO MICROPHONE

If the sound signal is transmitted uncompressed in order to ensure low latency, the data rate must be at least four times higher than when using data compression. To achieve this, we studied a method combining multi value modulation techniques to use frequency efficiently, with OFDM, which is resistant to reflections and other interfering signals. With this method, we hoped to reduce delay by manipulating the transmission parameters. We first reduced the time needed for fast Fourier transform (FFT) and error correction buffering by using a short OFDM symbol length and using an error correction code (convolution code) compatible with a short code length. Then, we minimized the buffer time for signal processing by making the audio signal sample length an integral multiple of the OFDM symbol length and error correction code symbol length. The transmission parameters, taking these results into consideration, are shown in Table 3. The data rate for transmitting an uncompressed audio signal sampled at 48 kHz with 24-bit quantization, which is the standard quality in studio environments, is 1,152 kbps. Parity coding able to detect errors in the audio signal in single-word (24-bit) units was added to this, assuming errors would be corrected in the receiver. Convolution coding and Viterbi decoding, which have low latency, were used for error-correction coding and decoding. The low-latency specified digital radio microphone transmission method has three transmission modes, as shown in Table 3. In the standard microphone mode, the uncompressed audio signal is transmitted with 16QAMOFDM modulation. The interference-tolerant mode uses a method called instantaneous companding12) to compress the information by 50%, and then uses QPSK-OFDM for transmission to improve performance when there is noise or other interference. The in-ear monitor mode uses instantaneous companding to reduce the information by 50%, before sending a two-channel stereo audio signal,[7].

Table 3: Low-latency specified digital radio microphone transmission parameters.

Mode			Standard Mic.	Interference tolerant mic.	In-ear monitor
Data coding		Analog audio signal	Mono	Mono	Stereo
		Quantization (bits)	24	24	24 (2 channels)
		Sampling freq. (kHz)	48		
		Data compression	Uncompressed	Instantaneous comp./decomp.	Instantaneous comp./decomp/
		Transmitted data (bits)	24	12	12 (2 channels)
		Data rate (kbps)	1,152	576	1,152
		Parity coding	CRC*1-2		
Transmission path coding		Error coding, coding rate	Convolution coding, 2/3		
		Primary (carrier) modulation	16QAM	QPSK	16QAM
		Secondary modulation	OFDM		
		Effective symbol length (μs)	78.4		
		Symbol length (μs)	83.3		
		Guard interval (μs)	4.9		
		Carrier interval (kHz)	12.75		
	No. Carriers	Total	46		
		Data	39		
		SP*2	3		
		TMCC*3	3		
		CP*4	1		
		Transmission bandwidth (kHz)	586.5		

*1 Cyclic Redundancy Check.
*2 Scattered Pilot.
*3 Transmission and Multiplexing Configuration Control.
*4 Continual Pilot.

VII CONCLUSION

The paper describes about an overview of radio microphone transmission methods, described the state of frequency migration for specified radio microphones. Till now, the 770 to 806 MHz band could be used by specified radio microphones anywhere in the country without interference. Analog microphones never had an issue with latency. Such operation will still be possible anywhere in Japan after the switch over to the 1.2-GHz band, and linear PCM audio transmission with high quality and low latency will be able to be achieved. However, the new bandwidth must be shared with other radio-standardized tasks*5, so the new digital radio microphones will have to be tolerant to interference and have very low latency.

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